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# FALSE DISCRETE TARGETS IN THE EN ROUTE SYSTEM


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DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA



JUNE 1978

FINAL REPORT

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A companion report concerned with ringaround targets is FAA-RD-77-12, IV, System Definition and Investigation of the On Site Processing of En Route Sensor Signals, Addendum, Investigation into Possible En Route On Site Beacon Ringaround Discriminates, by J. W. Thomas (February 1978).

16. Abstract


This report describes the results of a two year study concerning the problem of false discrete target reports which appear in en route system.

False target rates from selected secondary radar sites in the en route system are given. Six candidate fixes which attack the problems associated with these rates are examined.

False reports are divided into ringaround, splits, and reflections. A false report not classified as a ringaround or a split is classified as a reflection.

Several fixes against the ringaround type of false target are available and one of them, based on the double coverage provided in the en route system, is recommended for implementation. A fix against the split type of false target report is available and consideration of implementation is recommended.

A fix against the reflection type of false target is recommended in the special case where the physical reflector can be identified.


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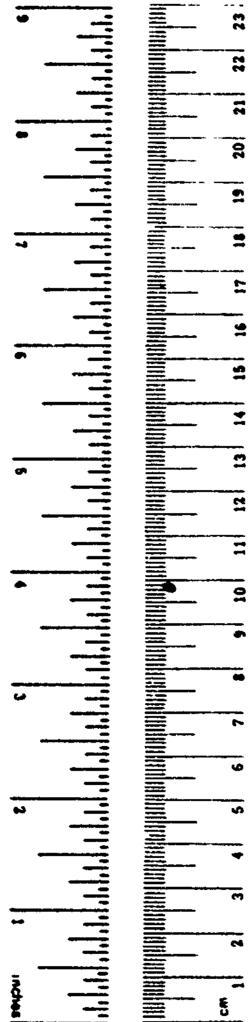
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

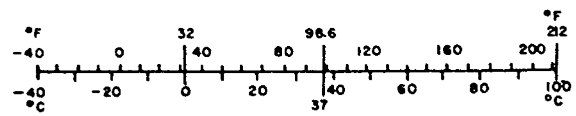
| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (weight)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| Tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.




## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (weight)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



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## APPENDICES

# ABBREVIATIONS

| | |
|---|---|
| ACP | Azimuth Change Pulse |
| APL | The Applied Physics Laboratory of Johns Hopkins University |
| ARTCC | Air Route Traffic Control Center |
| ARTS | Automated Radar Terminal System |
| ATS | Air Traffic Service |
| BFTA | Beacon False Target Analysis |
| CD | Common Digitizer |
| CDC | The long range radar located near Cedar City, UT |
| CE | Compute Element |
| CSC | Computer Sciences Corporation |
| CY | Calendar Year |
| DART | Data Analysis and Reduction Tool |
| FL | Flight Level (also Florida) |
| ft | feet |
| IND | The long range radar located near Indianapolis, IN |
| IOCE | Input/Output Control Element |
| ITT | Internal Target Table |
| JWT | J.W. Thomas, System Definition and Investigation of the On Site Processing of En Route Sensor Signals Addendum Investigation into Possible En Route On Site Beacon Ringaround Discriminates, FAA-RD-72-12, IV (February 1978) |
| LDB | Limited Data Block |
| MCI | Mode C Intruder |
| milli | one part in one thousand |
| min | minutes of time |
| MSG | Message |
| NAFEC | National Aviation Facilities Experimental Center |
| NAS | National Airspace System |
| NEN | The long range radar located near Jacksonville, FL |
| nmi | nautical miles |
| NYC | The long range radar located near New York City, NY |
| PVD | Plan View Display |
| QAS | The long range radar located near Las Vegas, NV |
| QWO | The long range radar located near London, OH |
| R,D&E | Research, Development and Engineering |
| RIN | Radar Input Processing Subprogram |
| RSB | Radar Sort Box |
| RTG | Beacon/Primary Radar Message Processing Subprogram |

ABBREVIATIONS (continued)

| | |
|---|---|
| SAR | Systems Analysis Recording |
| sec | seconds of time |
| SRDS | Systems Research and Development Service |
| VAD | The long range radar located near Valdosta, GA |
| ZID | The Indianapolis Air Route Traffic Control Center |
| ZJX | The Jacksonville Air Route Traffic Control Center |
| ZLA | The Los Angeles Air Route Traffic Control Center |
| ZNY | The New York Air Route Traffic Control Center |

## 1. INTRODUCTION

The work documented in this report is principally in response to Request for Research, Development and Engineering Effort AT-500-16, dated April 14, 1976, in which the Air Traffic Service requested the Systems Research and Development Service (SRDS) "to determine if any discriminates exist between actual and false beacon reports".

SRDS has issued two Interim Reports on the subject. The first, dated February 1977, showed that several discriminates against false beacon targets seemed to be available and indicated what they were.

To develop these ideas further contractors were assigned various development efforts.

The Applied Physics Laboratory of Johns Hopkins University (APL), working under contract DOT-FA75WA-3553, studied the problem of ringaround targets from the point of view of their run length characteristics.

The Computer Sciences Corporation (CSC) developed the algorithms proposed in the February 1977 report to the point where test versions of several of them could be evaluated. This work was performed under contract DOT-FA76WA-3815.

The second Interim Report dated February 1978, provided the results of some analytical calculations of the proposed algorithms and estimates of core and timing costs associated with each of the algorithms.

The APL work excepted, this Final Report summarizes the SRDS work concerned with false target discriminates. The APL work stands alone as a separate report which is referred to several times in this Final Report.

Section 2 of this report is a brief overview of false discrete target reports and their supposed origins.

Section 3 describes six fixes to the problems of false reports. These fixes are generally in the form of algorithms to the software of the NAS Stage A computers.

Section 4 describes how each of the algorithms is evaluated. The actual evaluation is described in Section 5 and the effectiveness of each of the fixes is considered. In Section 6 a conscientious effort is made to review the difficulties to be encountered if each of the algorithms is implemented.

Conclusions are given in Section 7 and Recommendations are discussed in Section 8.

## 1.1 Acknowledgements

Many persons have contributed to Project 122-111-01, False Target Discriminates since its inception in April of 1976.

F. Mullin, then of SRDS, provided advice and counsel concerning this project until he left SRDS in early 1977 and sporadically since then.

The six fixes were coded as algorithms, tested and the machine analysis was performed by the following personnel of the Computer Sciences Corporation (CSC): J. Corliss, N. Gundersen, J. Henrietta, E. Jones, L. Kuhn, L. Mannino, A. Montgomery, F. Niazy, B. Peterson, and G. Senn.

The CSC work was performed under the technical direction of J. Spalding of SRDS.

J. Held, R. Lautenschlager, and S. Hauser of the MITRE Corporation participated in a review of the software estimates of the algorithm which resulted in the loading estimates described in Section 6 of this report.

J. Thomas of APL analyzed the ringaround phenomena using tapes and other data supplied by R. Delaney of the National Aviation Facilities Experimental Center (NAFEC).

R. Copes of the Air Traffic Service (ATS) with R. Delaney of NAFEC prepared a code which may prove useful in implementing some of the fixes.

C. Ryman of ATS acted as liason between his service and SRDS.

The following subsections of this report are taken bodily from the CSC Final Report for Beacon False Target Discrimination Task 2 Concept 5 (February 1978): 3.4.1, 3.4.1.1, 3.4.1.2, 3.5.1, 3.5.1.1, 3.5.1.2, 3.6.1, and 3.6.1.1. Appendix B is also taken from that report.

## 2. THE NATURE OF FALSE DISCRETE TARGET REPORTS

It is usual to classify false target reports into (1) ringaround, (2) splits, and (3) reflection. Each class is believed to arise from a different cause and shows different characteristics on the Plan View Display.

### 2.1 False Target Reports, Ringaround

It is reasonable to assign the cause of ringaround target reports to leakage of energy of the P1-P3 pulses from the backlobe of the directional transmitting antenna. This antenna consists of a microwave feed to a large sail. Energy from the feed is mostly reflected by the sail to form a narrow beam of interrogation energy. However, some may leak over the top of the sail. When this happens an aircraft transponder may respond to these leaked interrogator pulses.

The characteristics of the false response in this case will be in form of a target report which (1) has the same range as a true target report and (2) is at an angle of 25° or more above the horizon. In many cases several reports will occur on the same scan. All these reports will tend to form a ring of radius equal to the distance of the aircraft from the interrogator.

Although small from the point of view of rates, (See subsection 4.1.1) ringaround reports can be annoying to the controller. They tend to occur in bunches. Frequently, due to overlap, the limited data blocks (LDB's) associated with ringaround reports are unreadable. A group of ringaround reports can take up enough space on the plan view display so that information displayed in the same position as a group of ringaround LDB's is completely obscured.

For a recent detailed discussion of ringaround see J. W. Thomas, System Definition and Investigation of the On Site Process of En Route Sensor Signals Addendum Investigation into Possible En Route On Site Beacon Ringaround Discriminates, FAA Report RD-77-12, IV (February 1978), especially Section 6 of that reference. Hereinafter Thomas' report will be referred to as JWT.

Consistency in the definition of ringaround is not always followed in this report. For purposes of "machine" analysis (subsection 4.3) the approach is "one ringaround, all ringaround". With this approach, if a target squawking 7257, say, rings once while passing over a radar site then all false reports with Mode 3/A code of 7257 are considered ringaround targets, even though as far as 114 nmi from the problem sensor.

For the purposes of "hand" analysis (subsection 4.2) only false reports within 30 nmi of a long range radar site are considered ringaround.

The different approaches give somewhat different results using the Los Angeles ARTCC data base. This is due to false reports from the QAS sensor with fairly long ranges which are associated with ringaround targets.

## 2.2 False Target Reports, Splits

The Common Digitizer uses fixed range cells 1/4 nmi in depth. If an aircraft crosses one of the cells during interrogation it will be reported as two separate reports, each with the proper identification and altitude, with a range difference of 1/8 nmi, and with a small bearing difference. This is called a range split.

If during the course of an interrogation an aircraft transponder is prevented from replying for seven successive interrogations and then resumes its replies, the Common Digitizer will form two target reports, each with the same range, with a small bearing difference between the two. This is called an azimuth split.

In either case further processing of the reports will ordinarily result in a track data block and a limited data block with a false target report displayed nearby. Either case is called a split.

Numerically splits are the largest class of false reports, (exceeding 2% of all reports at ZLA as depicted in subsection 4.1.2).

It does not appear feasible to treat the split type of false reports with a fix to the 9020 software. Such reports should be susceptible to a fix to the Common Digitizer.

## 2.3 False Target Reports, Reflection

If there is a sufficiently large reflecting surface which is sufficiently near the radar then an aircraft transponder may respond to the mirror image which is seen in the reflector, as well as to the radar itself. If this occurs an aircraft target will be reported at the bearing of the reflector and at a range equal to the sum of the distance from radar to reflector and from reflector to aircraft.

Only rarely can the reflector be identified with a physical object. More generally two target reports with the same mode 3/A code are identified on the same scan. The target report with the longer range is considered false even though a physical reflector cannot be identified.

Thus, reflected target reports are essentially used for balancing purposes. A false target report which is neither a ringaround report nor a split report is defined as a reflected target report.

On the plan view display reflected target reports generally appear as isolated position symbols with associated limited data blocks. The rates for reflected target reports associated with selected sites are given in subsection 4.1.3.

## 3. FIXES AGAINST FALSE DISCRETE TARGET REPORTS

Six fixes designed to discriminate against false discrete beacon target reports which appear in the en route system have been investigated. These fixes are described in this Section.

Fix 1 is designed to work against ringaround targets. Many ringaround false target reports are close in range to the radar and high in altitude. Any discrete target which is near a sensor and is comparatively high in altitude is a candidate ringaround target. A spare bit is set for each candidate and if, with this bit set, there is a track at the same range (± 1/4 nmi) and at the same altitude (± 100 ft) then the ringaround condition is declared.

Fix 2 is also designed to work against ringaround targets. With this fix a new type of radar sort box (RSB), called a split altitude radar sort box, is introduced. For this fix double radar coverage is required near a radar site which is experiencing ringaround problems. At lower altitudes the local sensor is designated preferred for the RSB's where ringaround occurs. At high altitudes a neighboring sensor, sometimes as much as 200 nmi distant, is designated preferred. Those familiar with radar processing in NAS Stage A will realize that these designations will eliminate ringaround targets associated with aircraft at the higher altitudes. Simultaneously, low altitude coverage will be supplied by the local sensor. This is a recommended fix.

Fix 3 is designed to work against the reflection type of false target. The position and orientation of the reflector must be known. All targets lying along the bearing containing the reflector are suspect. Appropriate conversion factors are applied to these targets, in effect "unreflecting" them to the location of the supposed true targets. If a target report at the unreflected location matches the reflected target in code and altitude then a reflection is declared. This fix is recommended for consideration in special cases.

Fix 4 is also designed to work against reflections. If on the same scan there are two targets with the same code and altitude then the closer target is considered true and the more distant false. This fix has the advantage that potentially all reflected targets are eliminated. However, if two aircraft mistakenly squawk the same discrete code then the more distant one may not be displayed.

Fix 5 is designed to work against ringaround. It was supposed that a false ringaround target has a shorter run length than the true target associated with it. If this were true a discriminate could be devised.

The run length characteristics of the ringaround type of false report actually are more complicated than they were hypothesized to be. This is documented in JWT and reported in subsection 5.5.

Fix 6 is designed to work against splits. If two targets are at the same range ($\pm$ 1/8 nmi), and their separation in azimuth is less than 1½ nmi, and they are squawking identical mode 3/A code and altitude then they are considered to form a split pair. This fix is recommended for consideration.

Except for Fix 2, all fixes may be coupled with computer software code which allows suppression of the limited data block (LDB) associated with a target while at the same time permitting the target symbol to be displayed. This software thus maintains the uncorrelated (and presumably false) target on the Plan View Display (PVD) while eliminating the limited data blocks. In this sense it cleans up the PVD. This code will be known in this report as the 4470 code, after its index number in the NAS Change Proposal system.

Subsections of this section contain discussion of each of the fixes and a description of the way each was coded. This coding was for test purposes and is designed to use the programmer efficiently rather than to optimize core usage or timing impact.

The numerical estimates of core and timing are based on the code as written. Estimates of code which will be efficient in operation are given in appropriate subsections of Section 6.

## 3.1 Fix 1 (against ringaround)

Any discrete target report which is within a given slant range of the radar source and above a given altitude is declared to be a candidate ringaround report. This declaration is made in the Common Digitizer (CD) and a spare bit in the message from the CD to the Data Receiver Group at the Air Route Traffic Control Center is set high.

The settings for slant range and for altitude are made so that many ringaround target reports will be flagged, but a minimum of true target reports will be flagged. For example, the initial recommendation for the range setting is 30 nmi at QAS and 11 nmi at IND.

The software is modified by means of a patch so that if there is a track with the same range as a candidate ringaround report the report is either destroyed or so modified that its display suggests the presence of a false report.

### 3.1.1 Fix 1 as coded

Figure 3-1 is a flow chart of an approach to Fix 1. The entries in the Tracking Data Table (TK/TH) are matched with those in the Radar Data Table (RT). According to the figure, RT entries are eliminated from this display chain if they correllate in mode 3/A code and are outside of a box centered on the TK coordinates of dimension 2.RTX times 2.RTY.

This code does not follow the spirit of Fix 1 and would have to be modified for further work.

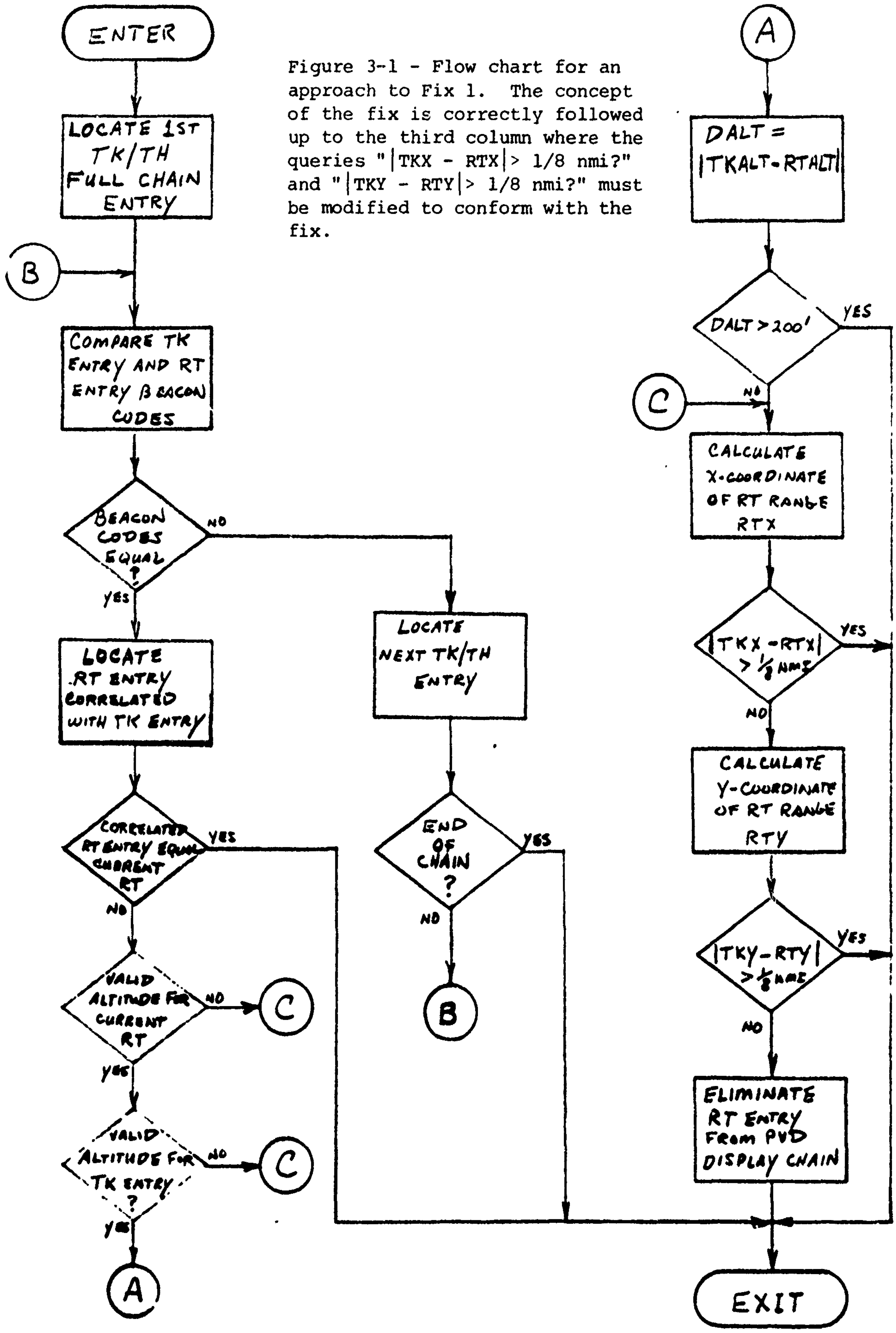



Figure 3-1 - Flow chart for an approach to Fix 1. The concept of the fix is correctly followed up to the third column where the queries "|TKX - RTX|> 1/8 nmi?" and "|TKY - RTY|> 1/8 nmi?" must be modified to conform with the fix.

Based on this flow chart the core usage of the code is as follows:

| | |
|---|---|
| Instructions | 92 words |
| Data and Tables | 40 |
| Sum | 132 words |

Contractor estimates timing in microseconds for this code as follows. The estimate is for the 9020A processor.

(8.9 * N5) + (15.2 + (16 * N6)) * N9)

where N5 is the number of reports passing selective rejection
N6 is the number of active tracks in the TK Table
and N9 is the number of reports with the spare bit set high.

Numerical estimates of quantities N5, N6, etc. may be found in subsection 4.1.4 and in Table 4-8 on page 56.

It has already been noted that the flow chart violates the spirit of Fix 1. The flow chart would have to be modified so that the queries in the third column "$|TKX - RTX| > 1/8$ nmi?" and "$|TKY - RTY| > 1/8$ nmi?" would be replaced by the singly query $|(TKX - Xo)^2 + (TKY - Yo)^2 - R^2| > \epsilon$ where (Xo, Yo) is the geographical location of the radar site and R is the radar range of the report projected onto the NAS data plane. $\epsilon$ would be of the order of 1/64 square nmi.

Further work on this fix has not been pursued since fix 2, described next, attacks the ringaround problem successfully.

### 3.2 Fix 2 (against ringaround)

This fix is designed to work against ringaround. It requires double radar coverage over a problem radar site. Implementation in NAS en route State A is particularly simple as it takes advantage of the radar sort box (RSB) system.

With this fix several RSB's near the problem radar are considered split altitude RSB's and the assignment of a report as to being either preferred or supplementary is made on the basis of altitude. Low altitude reports form the local site are preferred reports as are high altitude reports from a neighboring site. High altitude reports from the local sites are considered supplementary reports as are low altitude reports from the neighboring site.

In this fix a report without altitude information from the local site is considered preferred. A report without altitude information from the neighboring site is considered supplementary.

Table 3-1 summarizes these rules. For an example of how the fix would function at ZLA if QAS were a problem radar, refer to Figure 3-2.

### 3.2.1 Fix 2 as coded

Fix 2 was approximated for test purposes according to the flow chart of Figure 3-3. In this treatment the high altitude reports from the local site are discarded according to the box "No site match. MSG not entered in RT Table. Return to RINB for next message." The preferred/supplementary indicator of the more distant site is set to "preferred."

The test patch was to subprogram RIN. Core used for this test patch is

| | |
|---|---|
| Instructions | 39 words |
| Data and Tables | 43 |
| Sum | 82 words |

Timing in microseconds for this test patch is estimated to be

((6+(6*N8))*N5)+((56+(3*N8))*(N10-N14))+((113+(3*N8))*N14)

where N5 is the number of discrete reports which pass selective rejection
N8 is the number of adapted radar sort boxes (RSB's)
N10 is the number of reports in adapted RSB's
N14 is the number of high altitude reports in adapted RSB's

## 3.3 Fix 3 (against reflections)

Fix 3 is designed to eliminate false target reports associated with known reflectors. Given a reflector, it lies along a fixed bearing. All reports from that bearing are treated as potential reflected targets.

This fix is based in part on work by Lincoln Laboratory. The reference is A. G. Cameron, False Target Elimination at Albuquerque Using ARTS III Software, Lincoln Laboratory Technical Note 1974-12 (March 12, 1974).

Let RR and OR be the range and orientation of the reflector as in Figure 3-4. Further let XT and YT be the cartesian coordinates of the reflector. Thus given a potential false report as range RF and bearing θF, one calculates where an aircraft would have to be to generate such a report. The coordinates of the aircraft location are given by:

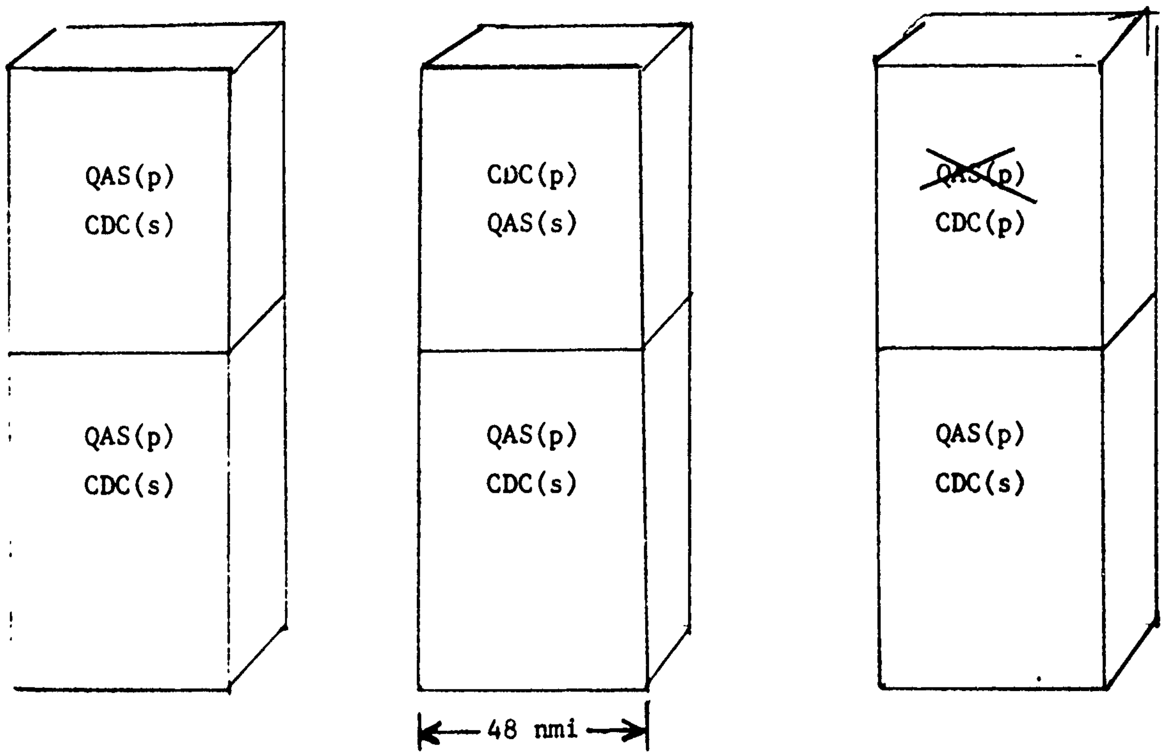
$$\begin{aligned} XT &= XR + (RF - RR) \sin (2\,\theta R - \theta F) \\ YT &= YR + (RF - RR) \cos (2\,\theta R - \theta F) \end{aligned} \qquad (3\text{-}1)$$

Table 3-1

Report Assignment

A discrete beacon target report in a split altitude radar sort box is assigned the preferred/supplementary indicator according to the altitude of the report.

| | Local Sensor | Neighbor Sensor |
|---|---|---|
| Lo Altitude | Preferred | Supplementary |
| Hi Altitude | Supplementary | Preferred |
| No Altitude | Preferred | Supplementary |




(a)
Preferred and supplementary reports as ZLA assigns them

(b)
Proposed reassignment of preferred and supplementary report

(c)
As tested

Figure 3-2 - Fix 2, as tested for ringaround at the Las Vegas, NV radar site (QAS). In the nine RSB's near QAS the reports from the QAS radar are considered preferred reports and those from the Cedar City, UT (CDC) site are considered supplementary as in (a). According to Fix 2 the ranking of preferred and supplementary is reversed for high altitude reports as in (b). For test purposes code was prepared which removed the QAS high altitude reports and set the preferred/supplementary indicator to preferred (c). This code imitates Fix 2 well enough to determine its effectiveness.

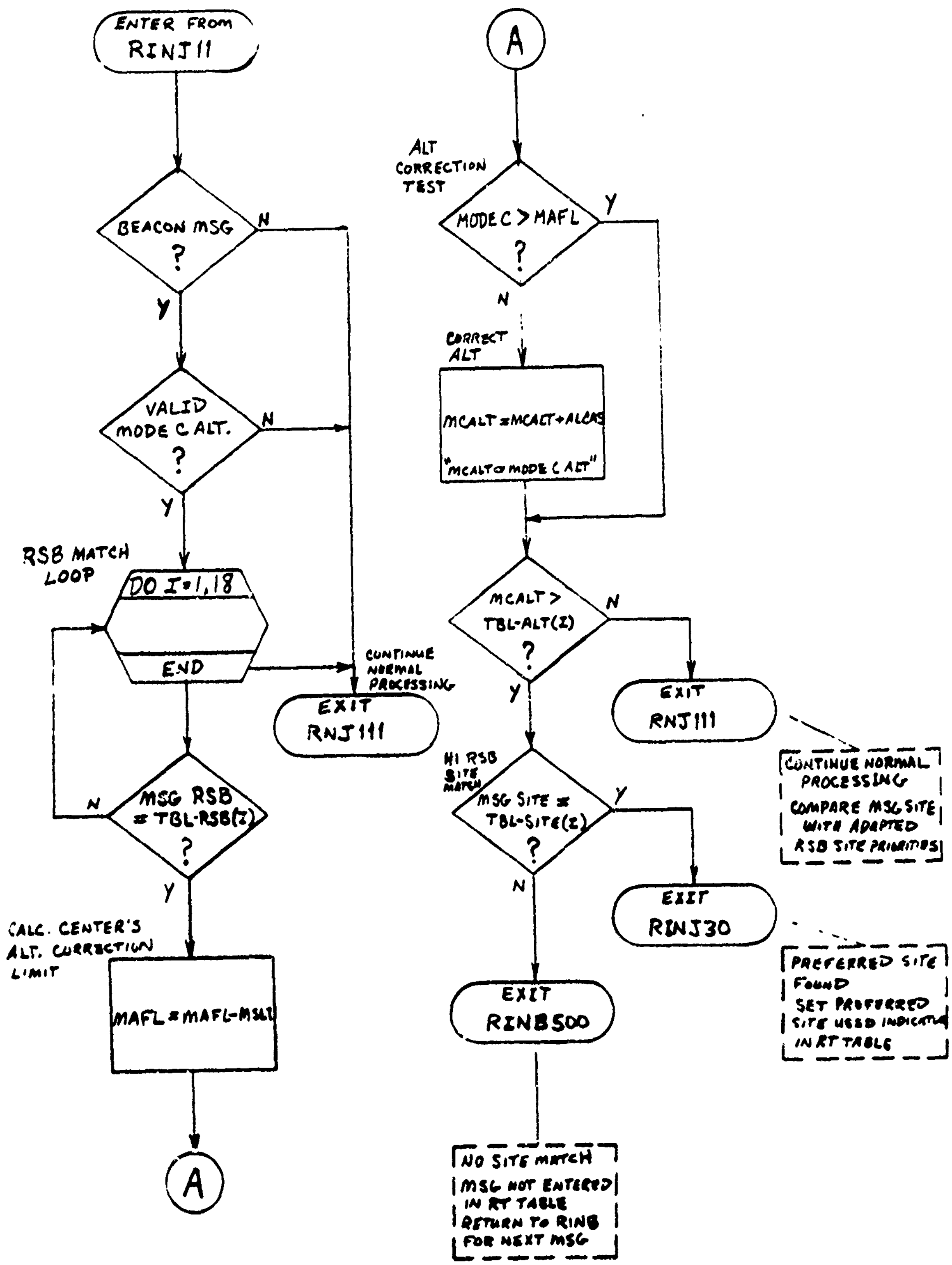



Figure 3-3 - Flow chart for the algorithm of Fix 2. Code was prepared based on this flow chart.

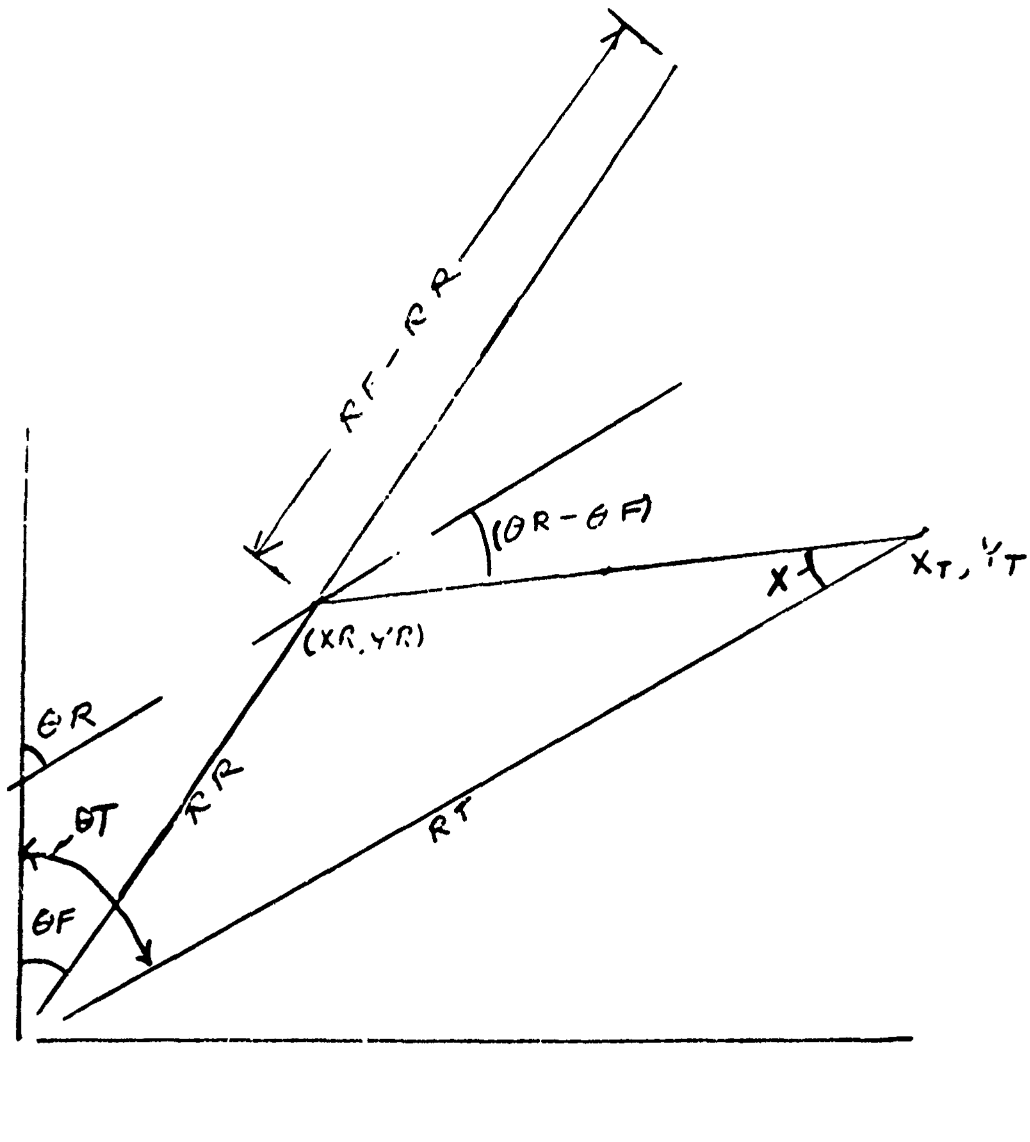



Figure 3-4 - The relationship between range of false target, (RF), that of the radar reflector (RR) the various angles involved and the position of the true aircraft target may be read off this figure.

If in fact there is an aircraft track or an aircraft report at the location calculated then the potential false report is considered to be indeed false and it is removed from the display.

There are two versions of this algorithm. The "A" version compares potential false reports against the tracks of the Tracking Data Table, TK/TH. The "B" version compares reports against a report file created especially for this algorithm. Both versions were coded for test purposes.

### 3.3.1 Fix 3 as coded

Figure 3-5, in three parts, is the flow chart from which the "A" version of this algorithm was coded for test purposes.

The core usage for the "A" version is as follows:

| | |
|---|---|
| Instructions | 152 words |
| Data and Tables | 44 |
| Sum | 196 words |

The timing estimate for this version is as follows. Times are in microseconds for the 9020A System.

$$(35 * N5)+((195 + (12 * N6)) * N12)$$

where N5 is the number of target reports which pass selective rejection
N6 is the number of active tracks in the system
and N12 is the number of targets on the problem bearing

The "B" version was coded as a patch to subroutine RIN. Two internal tables are required, indexed IDT and ITT. Table IDT requires 9 words for each reflector and three reflectors are allowed for test purposes.

Table ITT requires one entry of 10 bytes for each target report. For test purposes 640 words allow for 256 target reports.

Total core usage for the "B" version is

| | |
|---|---|
| Instructions | 166 words |
| Data and Tables | 717 |
| Sum | 883 words |

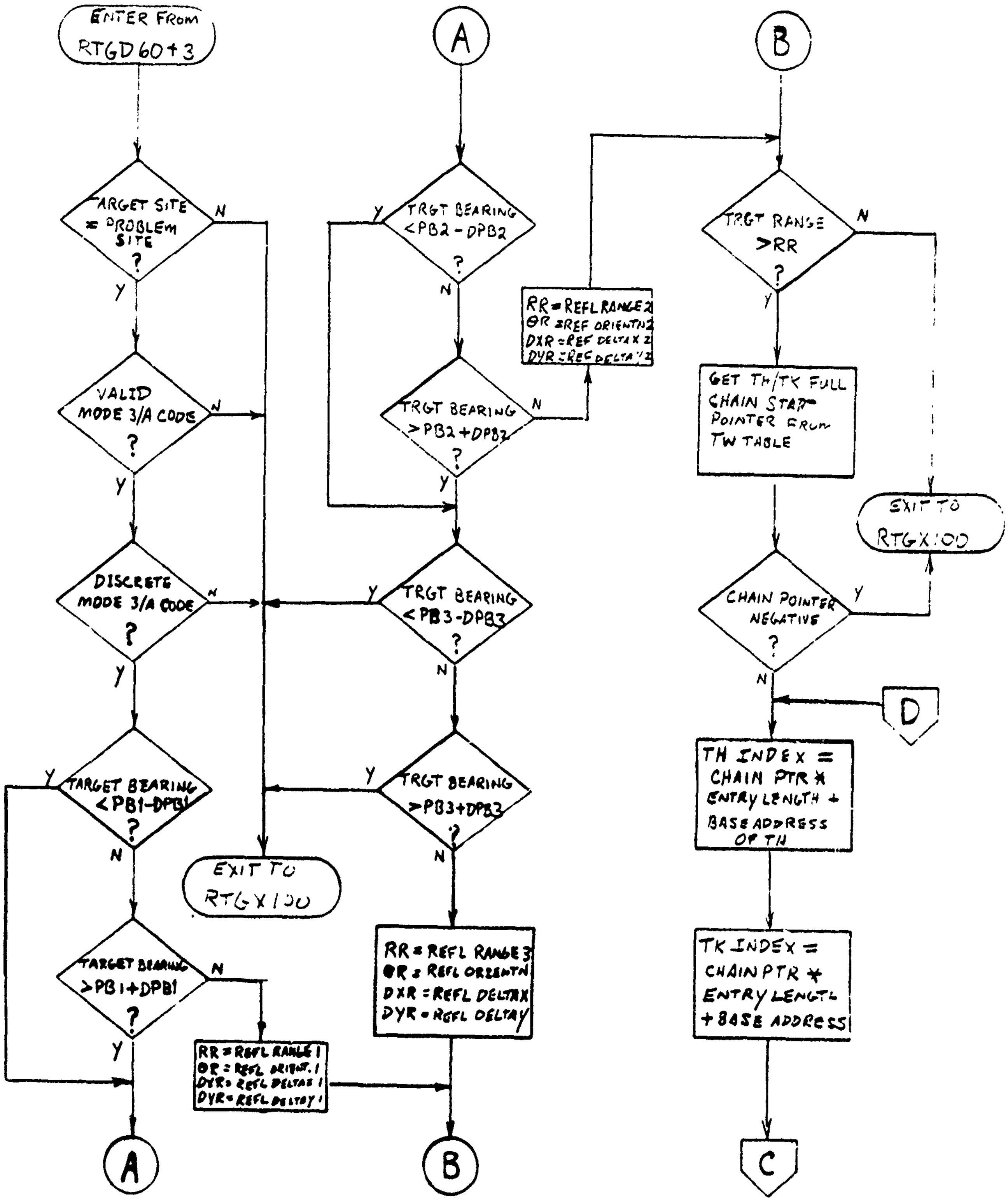



Figure 3-5. Flow chart for the "A" version of Fix 3 as coded. Page 1 of 3.

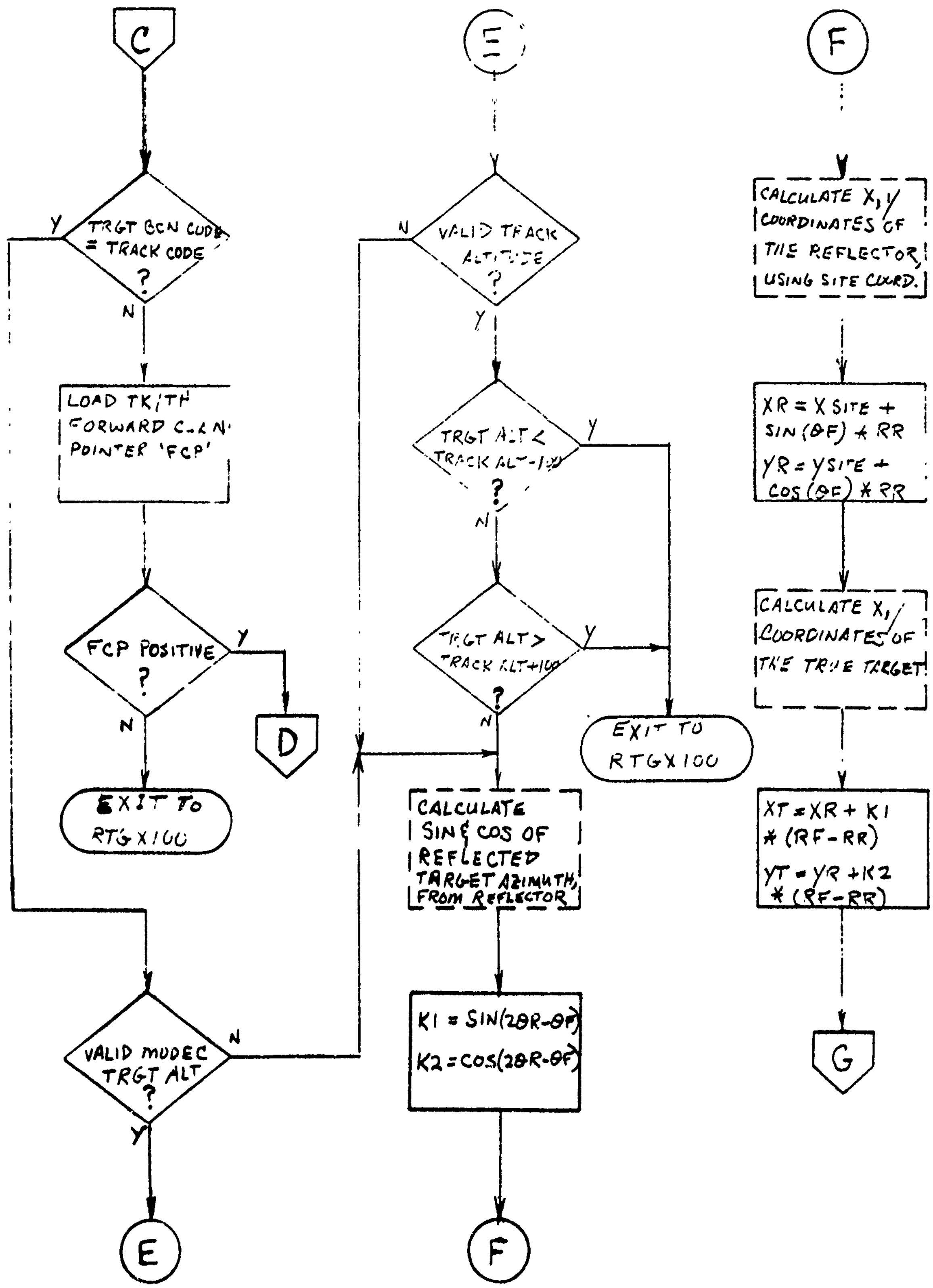



Figure 3-5. Flow chart for the "A" version of Fix 3 as coded. Page 2 of 3.

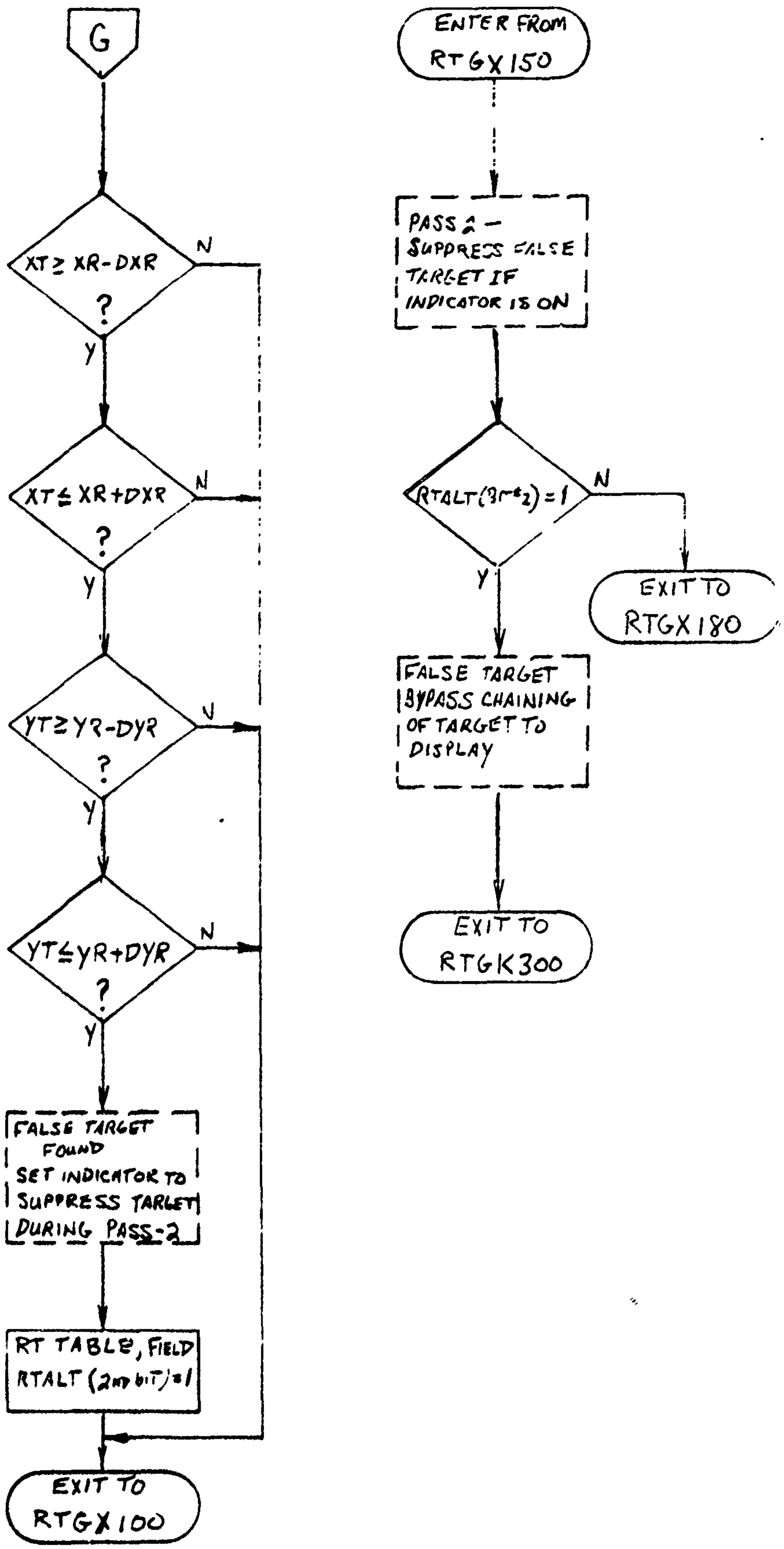



Figure 3-5. Flow chart for the "A" version of Fix 3 as coded. Page 3 of 3.

The time, in microseconds, required for this fix is as follows:

$$((54 + (12 * NA)) * NB) + ((238 + (6 * NC)) * ND$$

where NA is the number of scans of ITT for a new data insertion
NB is the number of target reports in the problem area
NC is the number of scans of ITT to find a match
and ND is the number of target reports which are possible reflections.

The numbers NA through ND are site dependent.

Generally NB should be only a little greater than NA. If a problem area is well populated NA may equal to fifty and NB to sixty. As coded, NC is one half the number of entries of ITT or 128 in this case. On average, ND is not expected to be greater than a value of one.

This fix is reminiscent of work done by MITRE for the terminal part of NAS. The reference is J.E. Freedman and J.C.C. Jagernauth, Filtering False Beacon Targets, MTR-6619, MITRE (February 28, 1974).

If two target reports from the same radar have the same Mode 3/A code then the report with the longer range is considered to be false and is generally suppressed.

Allowance is made for pseudo discrete codes by incorporating a "No Suppress" table into the algorithm of this fix. (By a "pseudo-discrete" code is meant a discrete mode 3/A code which is deliberately assigned to more than one aircraft. For example, on September 20, 1976, the IND radar was receiving reports from two aircraft each of which was squawking 4677.

### 3.4.1 Fix 4 as coded

As each beacon target report is obtained in the Radar Buffers Table (RH), by the Radar Input Processing Subprogram (RIN), information concerning the report is saved in a Table TX entry. See Figure 3-6 and 3-7. The TX entries are chained consecutively except the last entry points back to the first. Item TXFRT points to the first entry in the chain and item TXLST points to the last entry in the chain.

At any one instant, Table TX contains one scan of beacon targets. The time for a scan is determined from item RUSCN in the Radar Site Data Table (RU). Each time a new entry in Table RH is encountered, bookkeeping is performed to save only one scan of data. This is accomplished by incrementing item TXFRT.

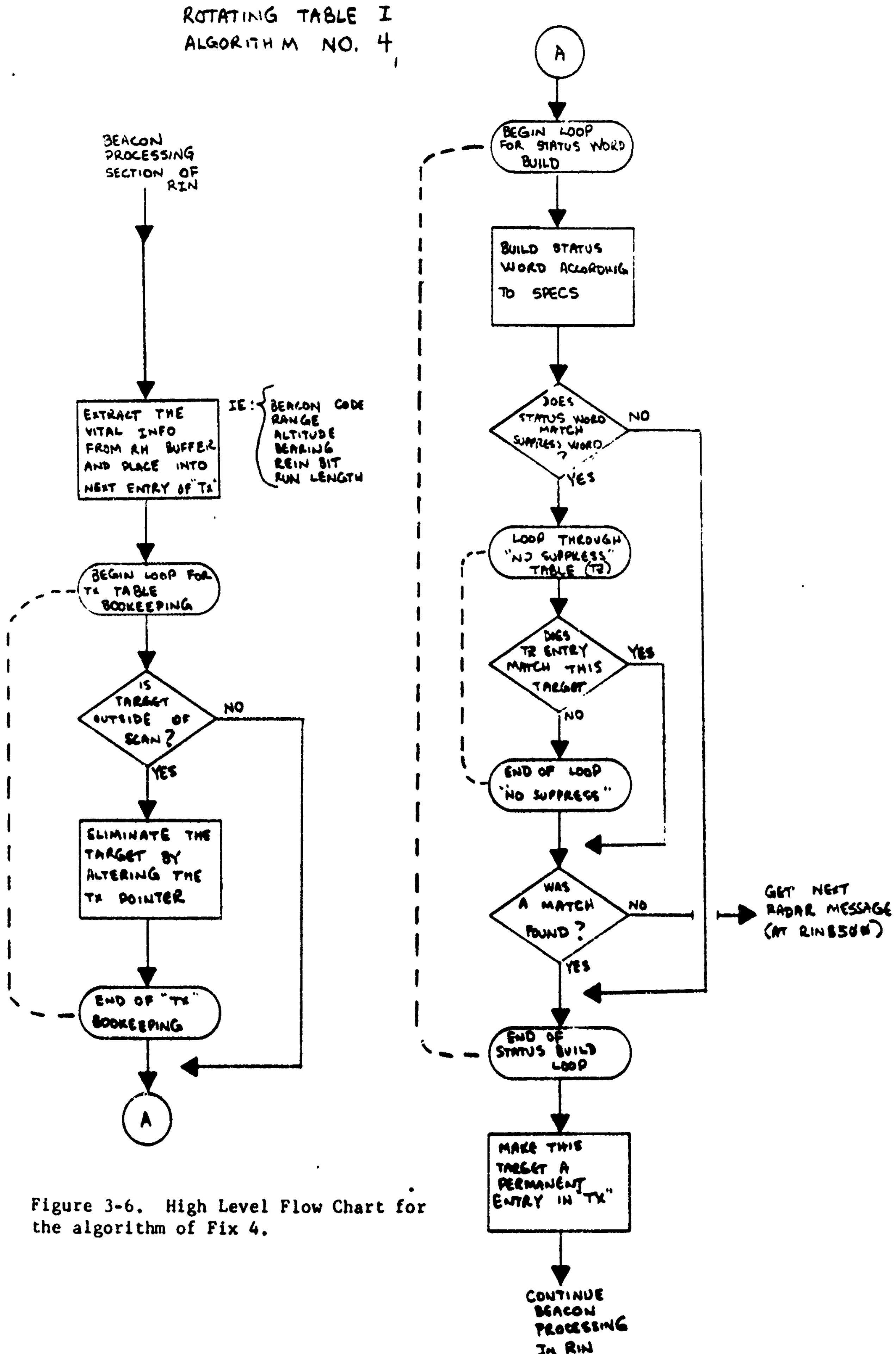



Figure 3-6. High Level Flow Chart for the algorithm of Fix 4.

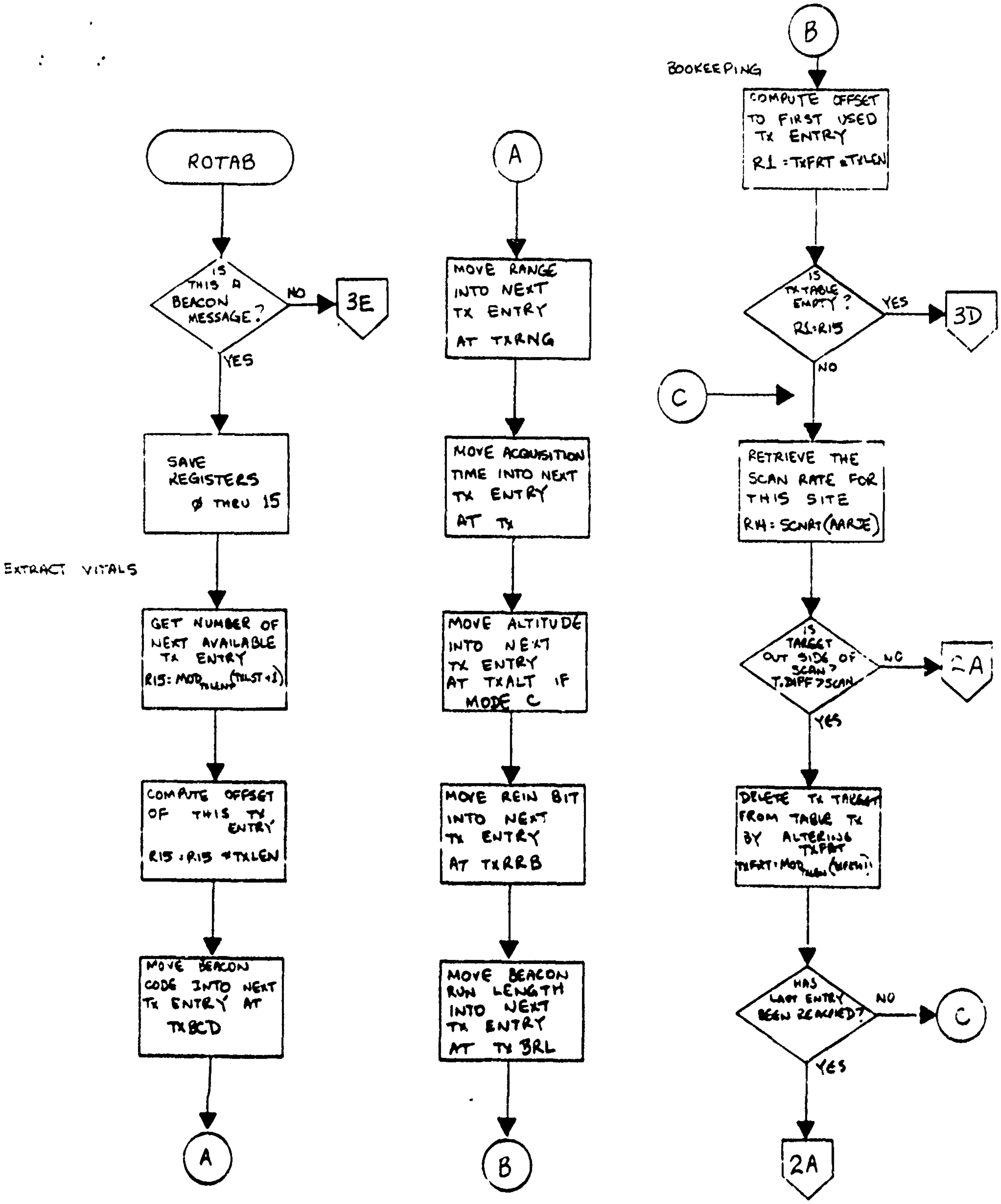
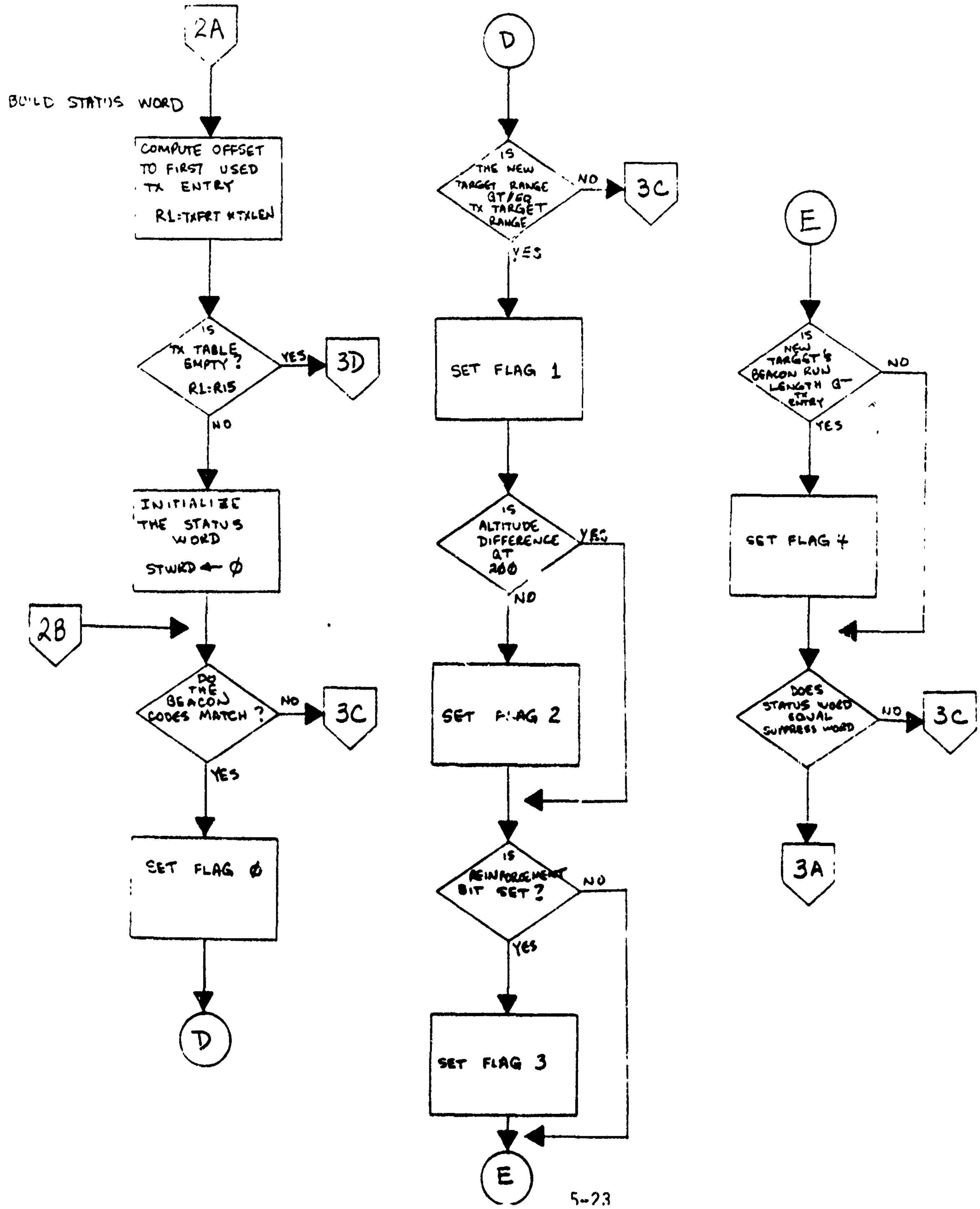



Figure 3-7. Detailed flow chart for the algorithm of Fix 4.
Page 1 of 3.




5-23

Figure 3-7. Detailed flow chart for the algorithm of Fix 4. Page 2 of 3.

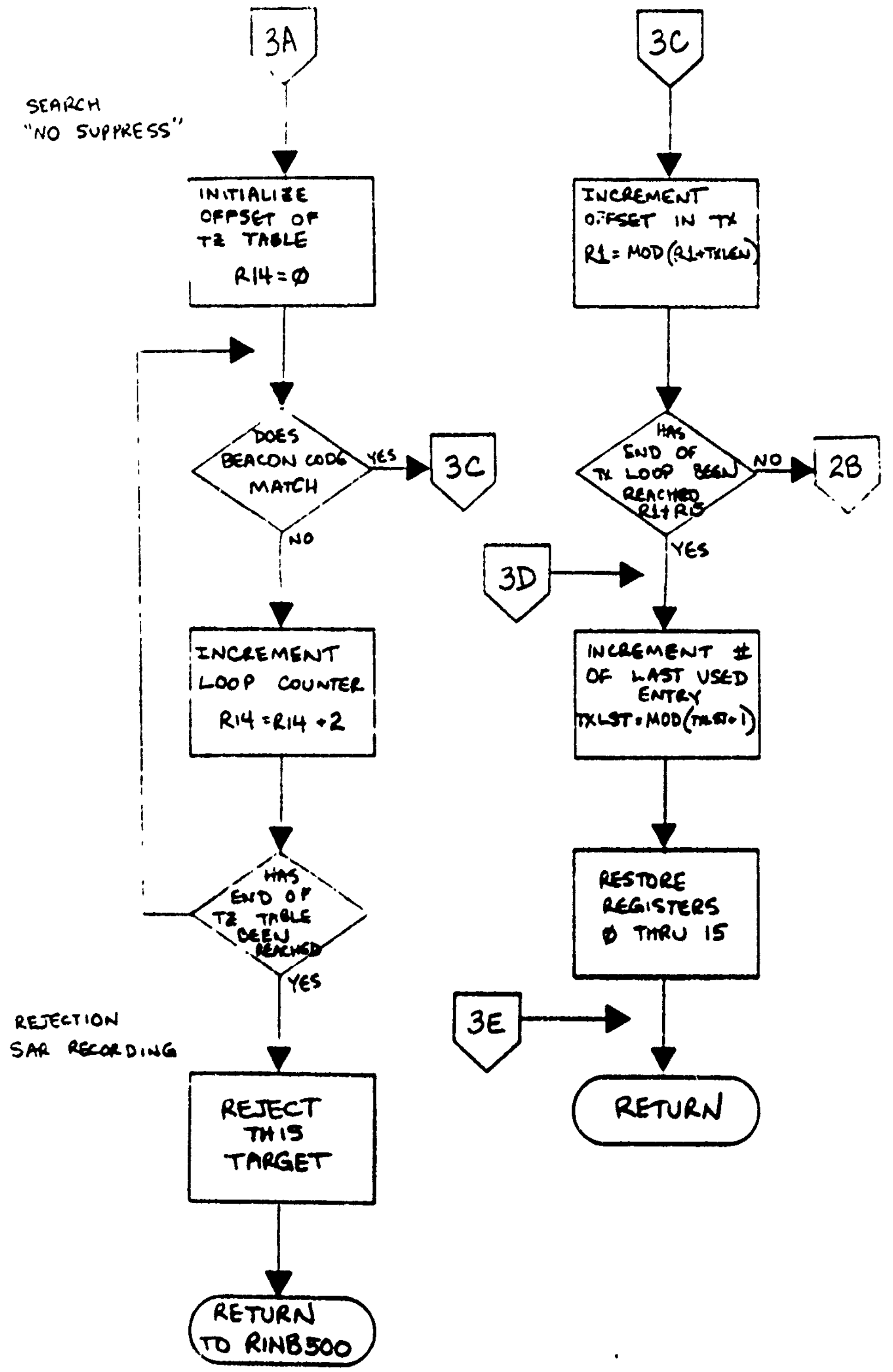



Figure 3-7. Detailed flow chart for the algorithm of Fix 4. Page 3 of 3.

A loop is executed to compare the data concerning this target with with those of each of the previously obtained targets. A "status word" is built indicating results of each comparison.

With the status word, the user may choose not to suppress a report if any combination of the following is true: (1) search reinforcement bit is set, (2) long beacon run length, and (3) altitude difference of report pair is greater than 200 feet.

There is also a Table TZ of pseudo discrete beacon which the user wishes not suppressed. The beacon code of the "candidate for suppression" is compared against each beacon code in TZ. If a match is not found, the target is suppressed.

#### 3.4.1.1 Tables Needed for the Algorithm of Fix 4

TQ1- "Scan Rate Table"
List of scan rates, one entry for each radar site adapted (maximum 30 - 16 bit entries). See Figure 3-8.

TZ -"Table of Pseudo - Discrete Codes"
List of Mode 3/A beacon codes of targets which are not to be suppressed (maximum 30 - 16 bit entries). See Figure 3-8.

TX - "Rotating Table"
Each TX entry contains the data concerning beacon targets processed by Algorithm 4 in Subprogram RIN. Data include: Beacon Code, Range, Altitude, Radar REIN.BIT, Beacon Run Length, and Acquisition Time. These targets are chained together consecutively utilizing two items (TXFRT and TXLST) which point to the first and last entries in the chain respectively (maximum 475 - 48 bit entries). See Figure 3-8.

#### 3.4.1.2 Timing Estimate and Core Usage for Fix 4 as coded

Timing Estimate Formula - values in microseconds:

$$(124 + (6 * (N7 * N5/N3))) * N5$$

where N3 is the rate of discrete target reports from the Common Digitizer
N5 is the rate of discrete target reports after selective rejection
and N7 is the number of different targets in the airspace of the radar.

Core Usage

| | |
|---|---|
| Instructions | 141 words |
| Data and Tables | 1494 |
| Sum | 1635 words |

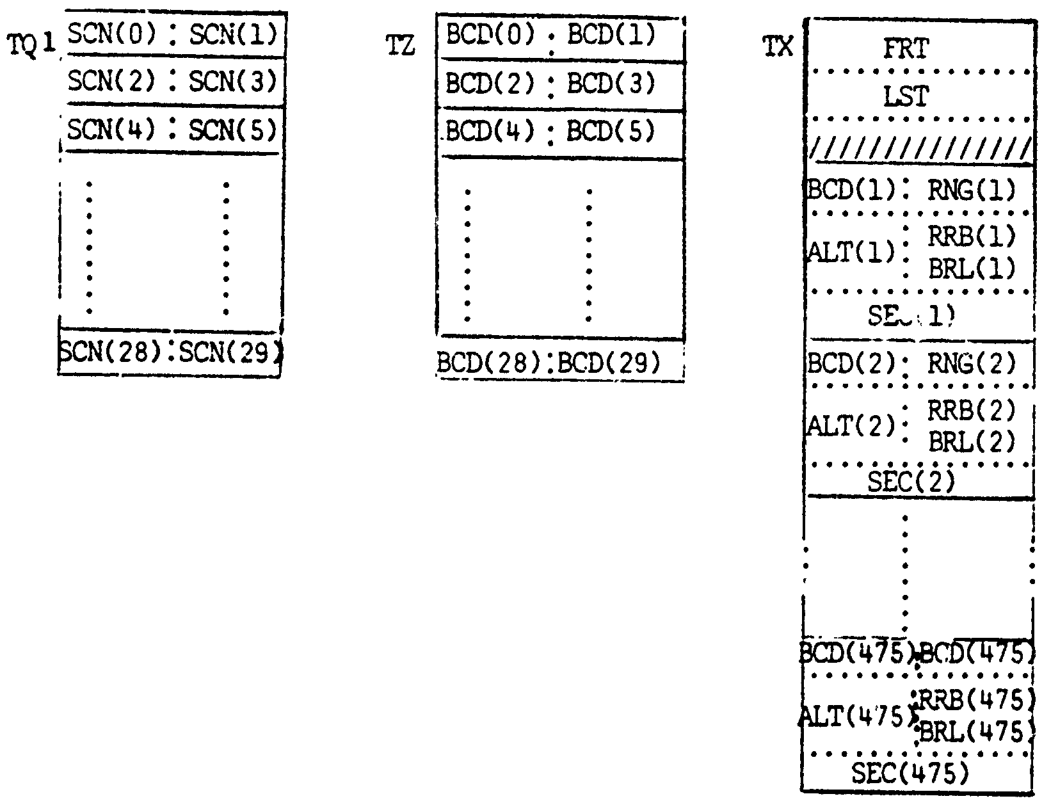



Figure 3-8 - Tables TQ1, TZ, and TX used in the algorithm of Fix 4 as coded.

### 3.5 Fix 5 (General)

This fix has undergone a series of metamorphoses during the course of the past two years. As presently conceived it discriminates false reports from true on the basis of run length.

An algorithm for this fix was coded which includes only provision for suppressing shorter run length targets. It can be selectively applied on the basis of radar sort boxes and has provision for 30 psuedo discrete codes.

#### 3.5.1 Fix 5 as coded

Figure 3-9 is a flow chart from which the code for the fix was prepared.

As each beacon message from the Radar Data Table (RT) is processed in the Beacon/Primary Radar Message Processing Subprogram (RTG), it is checked for correllation and beacon run length. If the entry is correllated with a track or the beacon run length exceeds a predefined parameter processing is terminated. Otherwise it continues as shown in the Figure.

##### 3.5.1.1 Tables Needed for Fix 5 as an Algorithm

A Table TZ contains beacon codes of target reports of pseudo-discrete codes. The item RTBEE in the RT table is compared against the TZ entry. If a match occurs the algorithm is terminated. Table TZ is sketched in Figure 3-10. It allows for thirty pseudo-discrete codes.

A Table TQ2 contains a list of selected radar sort boxes (RSB). The RSB associated with the RT Table entry is compared to each RSB entry in TQ2. If no match is found the algorithm is terminated. If there is an RSB match the target report is suppressed as a false target report. Table TQ2 is sketched in Figure 3-10. It allows for 30 RSB's.

##### 3.5.1.2 Timing Estimate and Core Usage for Fix 5 as coded

Timing Estimate Formula - values in microseconds:

$$(27.4 + (10.8 * (NR + N13))) * N15$$

where NR is the number of RSBs affected
N13 is the number of targets in "NO SUPPRESS" table
and N15 is the number of reports chained for display.

Core Usage

| | |
|---|---|
| Instructions | 52 words |
| Data and Tables | 56 |
| Sum | 108 words |

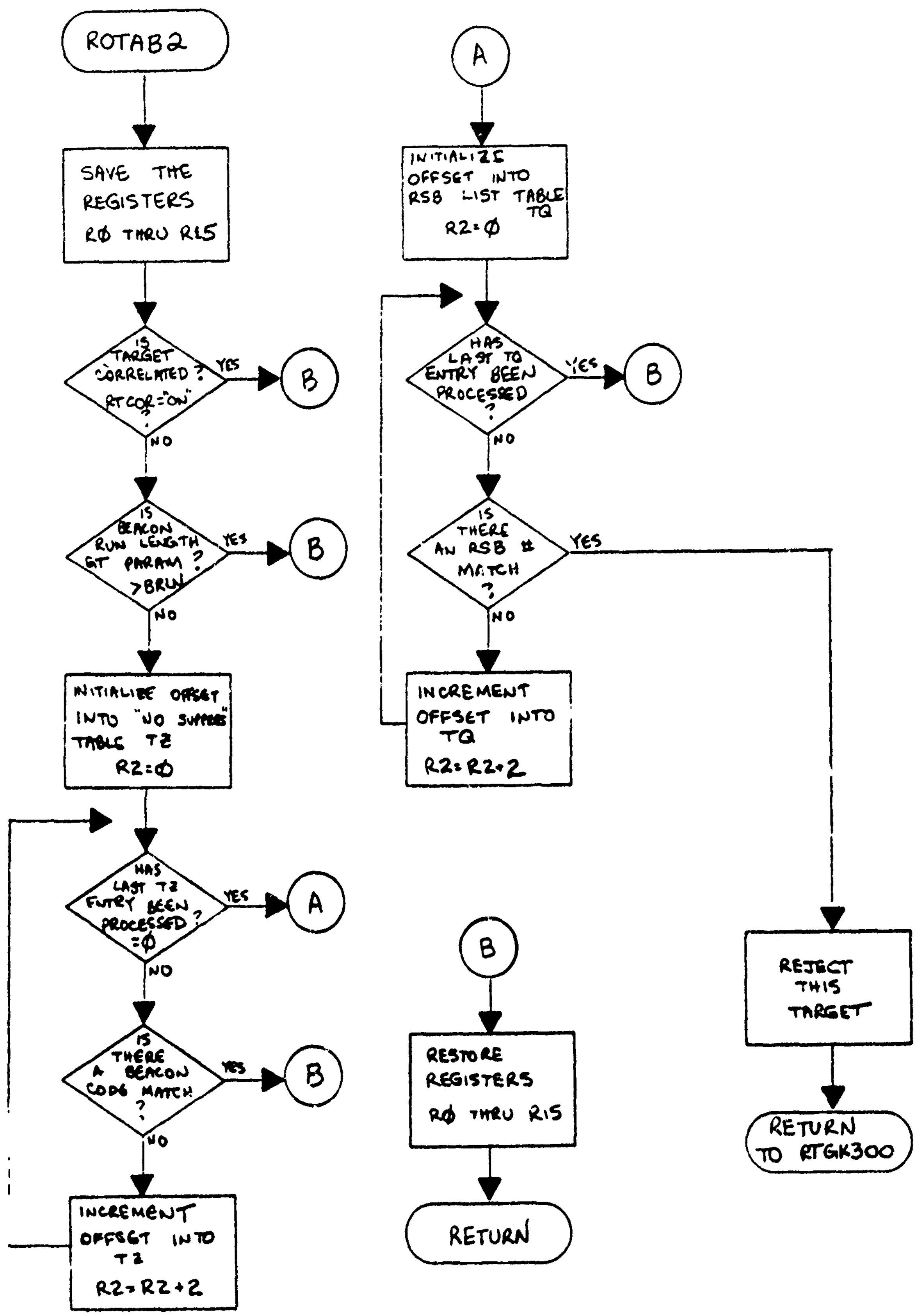



Figure 3-9. Flow chart for Fix 5 as coded.

TZ -

| | | |
|---|---|---|
| BCD(0) | : | BCD(1) |
| BCD(2) | : | BCD(3) |
| BCD(4) | : | BCD(5) |
| ⋮ | ⋮ | ⋮ |
| BCD(28) | : | BCD(29) |

TQ2-

| | | |
|---|---|---|
| RSB(0) | : | RSB(1) |
| RSB(2) | : | RSB(3) |
| RSB(4) | : | RSB(5) |
| ⋮ | ⋮ | ⋮ |
| RSB(28) | : | RSB(29) |

Figure 3-10. Tables TZ and TQ2 used in the algorithm of Fix 5 as coded.

### 3.6 Fix 6 (against splits)

This fix compares two mode 3/A target reports for a match in beacon code, range, bearing, azimuth difference and altitude. A match is considered to exist if the code of two reports is the same, range difference is less than 1/4 nmi and azimuth difference is less than 1-½ nmi. If the two reports both have mode C data, then the altitudes of both reports must be within 200 feet for a match to be found.

If a match is found then one of the reports is discarded. As coded as an algorithm for the IOCE, discard takes place depending on the presence or absence of the radar reinforcement bit and the Mode C validation bit.

Of the two reports either the old or the new report is discarded according to the following table. Y: Yes, N: No, and DC: Don't Care.

| New Report | | Old Report | | |
|---|---|---|---|---|
| Radar reinforced? | Mode C? | Radar reinforced | Mode C? | Report Discarded |
| DC | DC | Y | Y | Old |
| DC | DC | N | N | New |
| Y | Y | Y | N | New |
| N | Y | Y | N | New |
| Y | N | Y | N | New |
| N | N | Y | N | Old |
| Y | N | N | Y | New |
| N | Y | N | Y | New |
| Y | Y | N | Y | New |
| N | N | N | Y | Old |

#### 3.6.1 Fix 6 as coded

Figure 3-11 is a flow chart which gives an overview of the fix and Figure 3-12 is a more detailed flow chart. As each beacon message is obtained in Radar Buffer Table (RH) by subprogram RIN, the entire RH message of the target is saved in a table TX entry. There are five entries in the TX table, Figure 3-13, which are chained together consecutively except the last TX entry points back to the first TX entry. Two items (TXFRT and TXLST) point to the first and last TX entries in the chain. The TX Table is a "holding" table. Each time a new target is obtained, the entry pointed to by TXLST is released and the new target replaces it. TXFRT and TXLST are modified to make TXFRT point to the new target.

A loop is executed to compare the information of this target against that of each of the previously obtained targets. If the beacon code matches and the range, bearing, and altitudes are "substantially" equal, a split is declared and a target report will be suppressed.

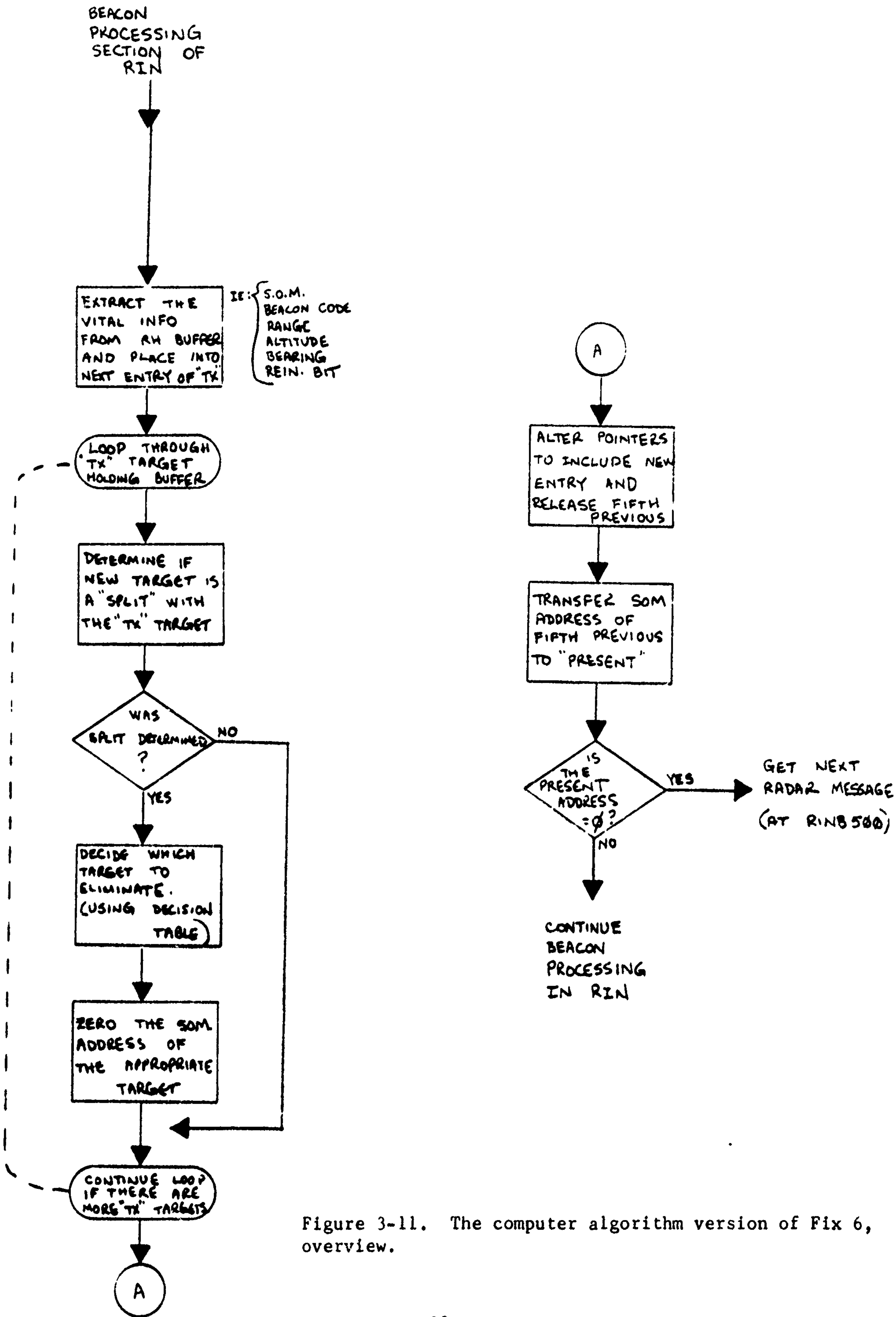



Figure 3-11. The computer algorithm version of Fix 6, overview.

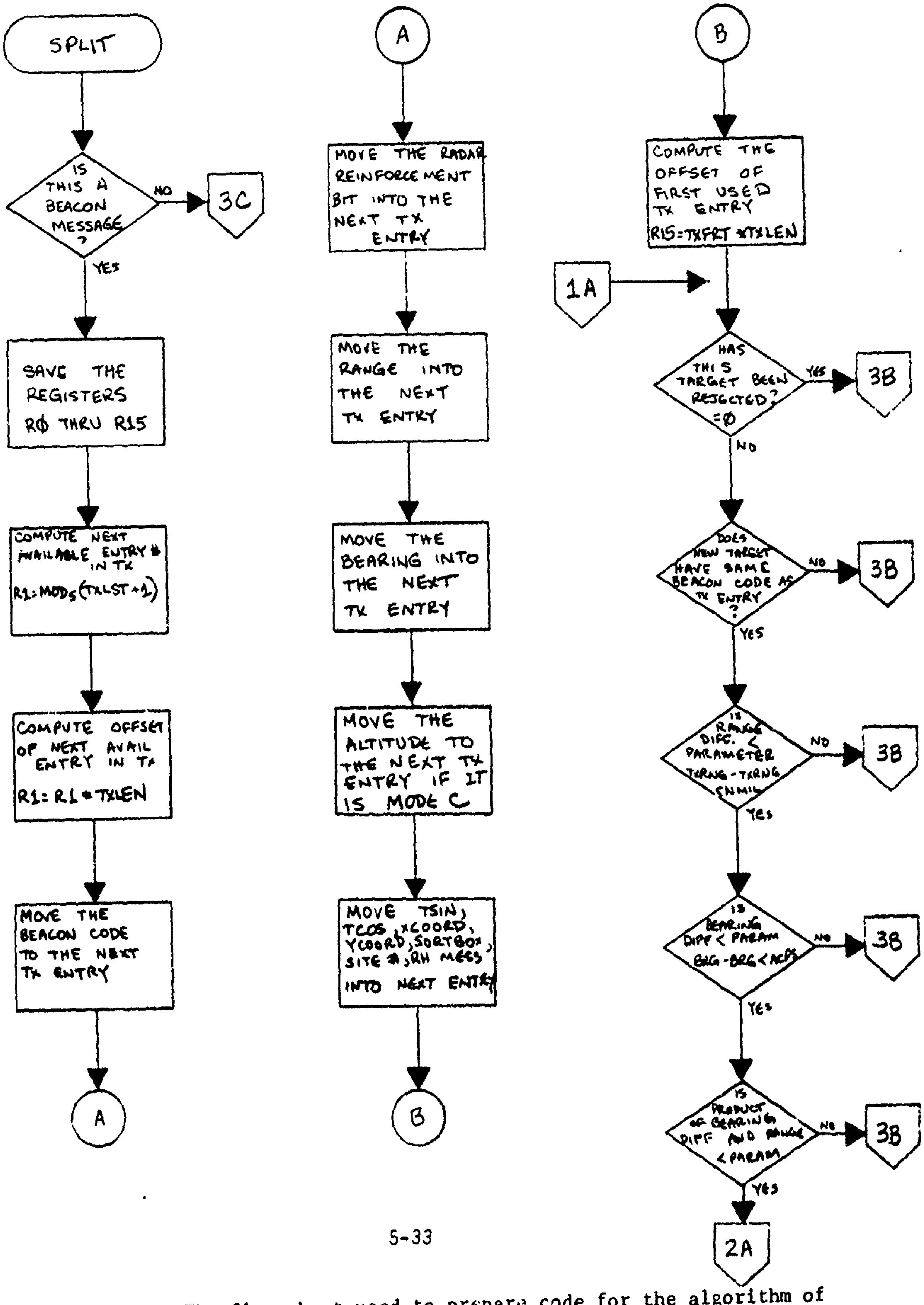





Figure 3-12. The flow chart used to prepare code for the algorithm of Fix 6. Page 1 of 3.

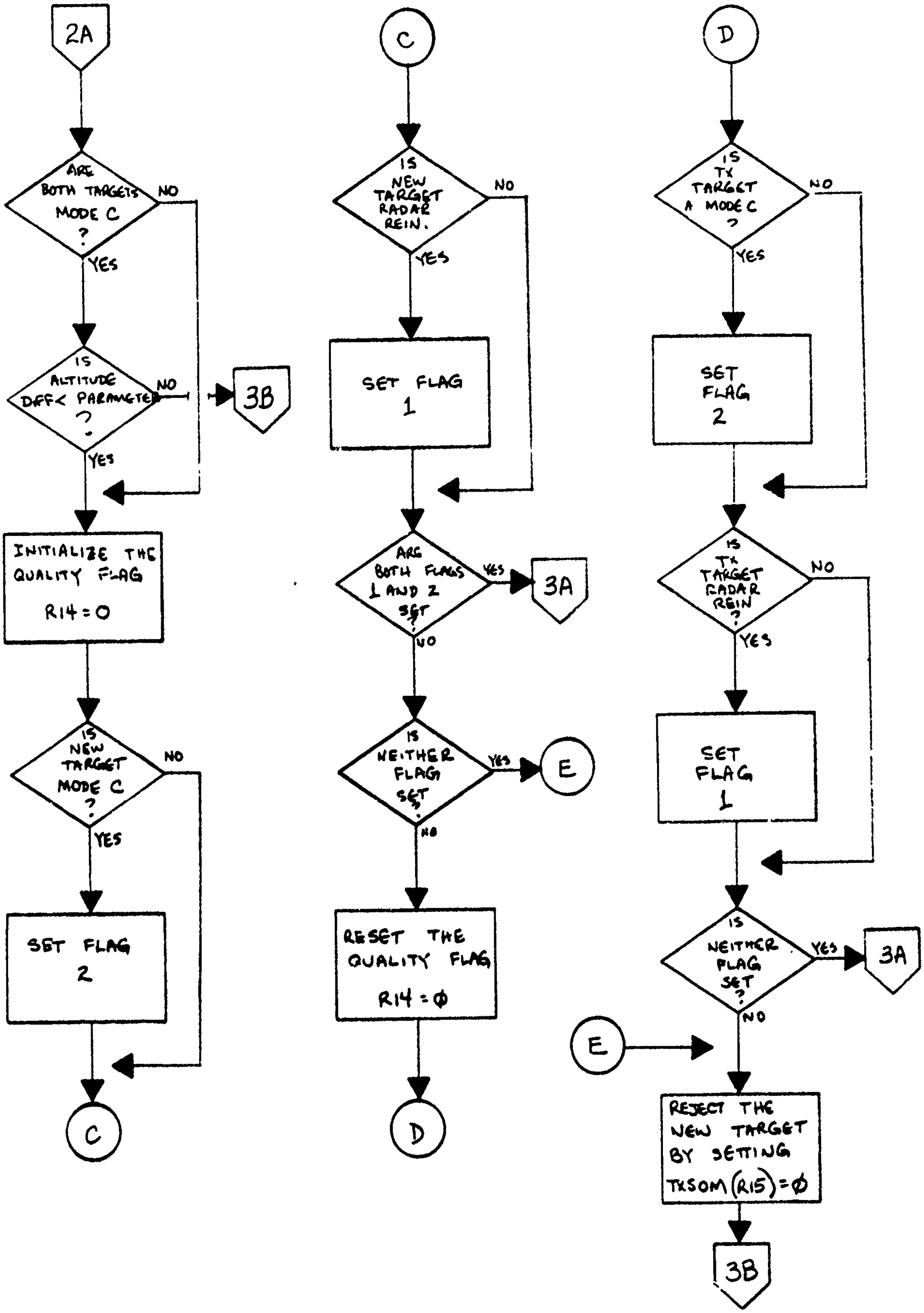



Figure 3-12. The flow chart used to prepare code for the algorithm of Fix 6
Page 2 of 3.

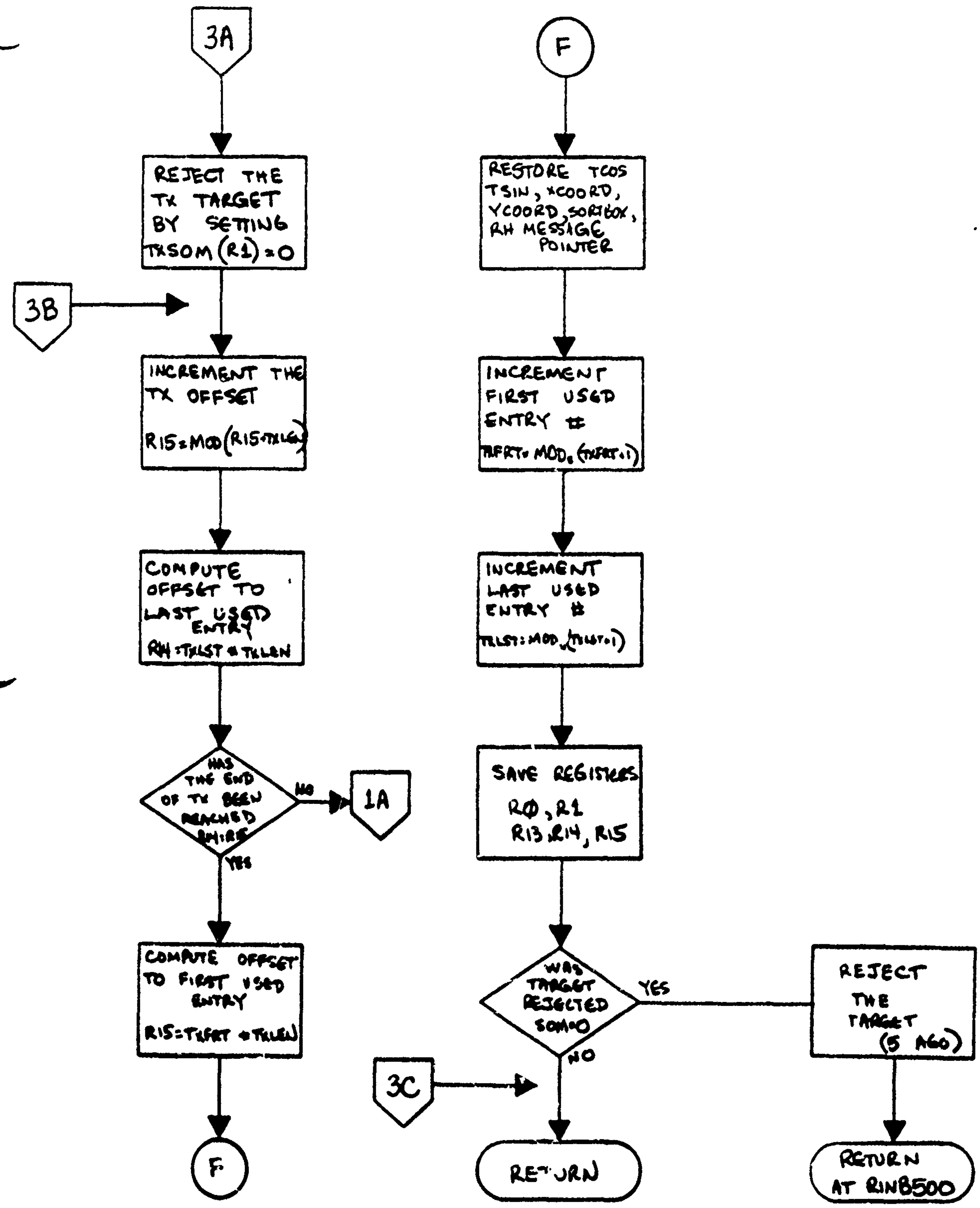



Figure 3-12. The flow chart used to prepare code for the algorithm of Fix 6 Page 3 of 3.

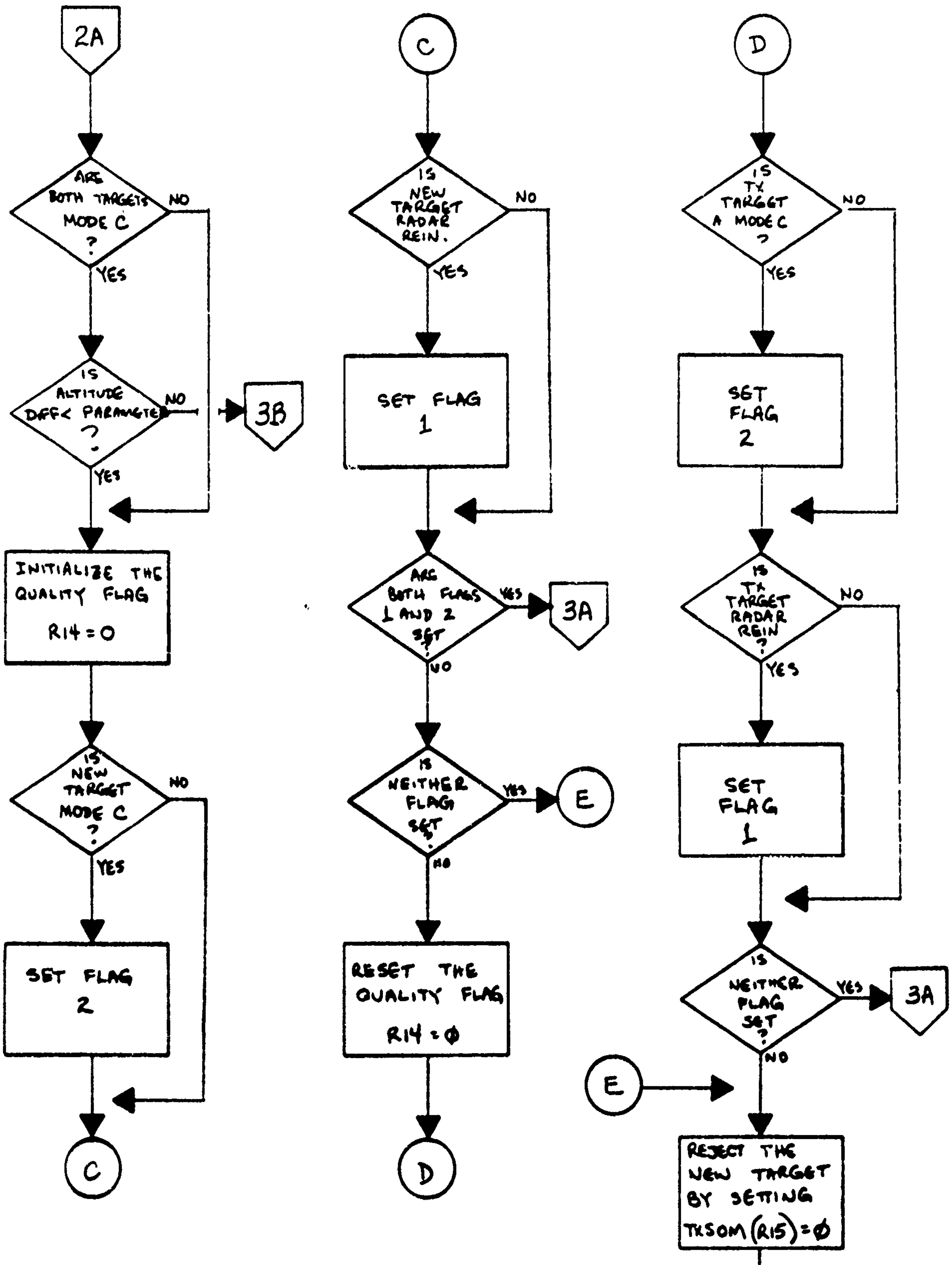



Figure 3-12. The flow chart used to prepare code for the algorithm of Fix 6 Page 2 of 3.

TX Entry:

| Word | | |
|---|---|---|
| 0 | TXTYP | |
| 1 | TXRRB/TXBCD | TXRNG |
| 2 | TXALT | TXBRG |
| 3 | TXCOS | TXSIN |
| 4 | TXY | TXX |
| 5 | RSB | TXSIT |
| 6 | TXRHB (RH MESSAGE) | |

TX Table:

| | |
|---|---|
| 0 | Target #0 |
| 1 | Target #1 |
| 2 | Target #2 |
| 3 | Target #3 |
| 4 | Target #4 |

Figure 3-13. Table TX used in the algorithm of Fix 6

At the finish of the loop, the last entry in the chain is released. A check is made to see if it was flagged as a false target and if so, it is suppressed. At this point the pointers are altered to reflect the new entry and the deletion of the entry just released.

### 3.6.1.1 Table Needed for Fix 6 as an Algorithm

TX - "Holding Target Table described in Figure 3-13"
Each TX entry contains the vital information of beacon targets processed by Fix 6 in subprogram RIN. TX contains 5 entries and thus holds 5 beacon targets. These targets are chained together consecutively. Two items (TXFRT and TXLST) are utilized to point to the first and last entries in the chain respectively. See Figure 3-13.

### 3.6.1.2 Timing Estimate and Core Usage for Fix 6 as coded

Timing Estimate Formula - values in microseconds:

$$(244 * N5) + (81 * N17)$$

where N5 - number of target reports which pass selective rejection
N17 - number of false target reports considered to be splits

Core Usage

| | |
|---|---|
| Instructions | 158 words |
| Data and Tables | 72 |
| Sum | 230 words |

## 4. ANALYZING THE FIXES AGAINST FALSE DISCRETE TARGET REPORTS

Two complementary methods of evaluating the effectiveness of each of the candidate fixes were pursued. Evaluation was made first by means of hand analysis, reviewing comparatively few instances very carefully. Evaluation was also pursued by machine analysis. Many instances were studied,but due to circumstances still unexplained errors must be assigned to the machine analysis which makes it less than perfect.

The best results were obtained for Fix 2. In this case the machine and hand analyses tend to support each other. For the other analyses the machine analysis is suspect.

Any analysis like this cannot be better than the data base which supports it. The data base for the study of false target discriminates is described in the following three subsections.

Finally, in subsection 4.4, there is constructed a model data base which is used in Section 6 to evaluate the expected timing impact of algorithms associated with the fixes. The data base for ringaround which is used in JWT is different than that described in this section. The reader must refer to JWT for its description.

### 4.1 The Data Base, General

Traffic samples from four Air Route Traffic Control Centers (ARTCCs) were taken in the form of Common Digitizer record tapes. Except for ZNY, each tape contains about 2 hours of data from each of two long range sensors. The ZNY tape contains data only from the NYC sensor.

Details of the tapes supplied from three ARTCC's are given in Table 4-1. The sensors recorded from each of the ARTCC's cover a substantial part of each one. This is estimated quantitatively in Table 4-2.

Table 4-2 shows, for ZID, that 586 Radar Sort Boxes cover this Center. Of this number, the IND sensor is the preferred sensor in 139 of the RSB's, and the QWO sensor is preferred in 98 of them. Thus, the data base covers 40 percent of the Center area if all sensors are functioning. The data base may be used to cover virtually the entire Center if the sensors not recorded are artificially failed. Either the IND sensor or the QWO sensor is used in each RSB except for 67 RSB's in the southern part of ZID.

Information on coverage of ZJX and ZLA is also given in the Table 4-2.

The sensor coverage is the "right" coverage for ZID and ZJX in the sense that it covers the essential part of each of these Centers. For ZID this is the Columbus - Indianapolis - St. Louis route, J-80 and J-110. For ZJX the coverage of the Miami - Atlanta traffic occurs in the RSBs where NEN and VAD are preferred.

The coverage for ZLA is probably overestimated in Table 4-2. The CDC-QAS sensor pair covers, as preferred RSBs, the area to the northeast of Las Vegas, NV. Relative to the western part of ZLA, this area is

Table 4-1
Data Base for False Target Discriminates

| Center | Sensors | Tape Slot | Date Recorded | | Time Start | Time Stop | Time Start | Time Stop | Targets Examined | Total Messages |
|---|---|---|---|---|---|---|---|---|---|---|
| ZID | IND | N928 | Mon | 9/20/76 | 2132Z | 2322Z | 1732EDT | 1922EDT | 66,398 | 317,900 |
| | QWO | N928 | Mon | 9/20/76 | 2132Z | 2322Z | | | 122,337 | |
| ZJX | NEN | S181 | Fri | 8/20/76 | 1047Z | 1321Z | 0647EDT | 0921EDT | 62,179 | 387,500 |
| | VAD | S181 | Fri | 8/20/76 | 1047Z | 1321Z | | | 54,166 | |
| ZLA | CDC | K396 | Mon | 11/1/76 | 1822Z | 2116Z | 1022PST | 1316PST | 56,870 | 407,900 |
| | QAS | K396 | Mon | 11/1/76 | 1822Z | 2116Z | | | 56,507 | |
| ZNY | NYC | M165 | Fri | 5/27/77 | 1626Z | 1821Z | 1226EDT | 1421EDT | 125,553 | |

Table 4-2

The Data Base in Terms of Radar Sort Box (RSB) Counts

| | Total number of RSBS | Sensor: and number of RSBs where it is preferred | | Number of RSBs where ARTCC is blind |
|---|---|---|---|---|
| ZID | 586 | IND:139 | QWO:98 | 67 |
| ZJX | 928 | NEN:102 | VAD:70 | 265 |
| ZLA | 970 | CDC:130 | QAS:76 | 292 |

| | Percentage with all sensors operating | Coverage of Data Base with sensor failing |
|---|---|---|
| ZID | 40% | 89% |
| ZJX | 18% | 71% |
| ZLA | 21% | 70% |

sparsely used.

### 4.1.1 The Data Base, Ringaround

A study of the CD records from ZID, ZJX, and ZLA revealed a total of 23 tracks in which a total of 439 ringaround target reports were noted.

Table 4-3 shows the breakdown of ringaround counts by Center. They are further classified as high or low altitude ringaround, as one of the fixes (Fix 2, New Type of Radar Sort Box) requires that an altitude be selected above which it is effective against ringaround and below which it is not.

If FL235 is selected as this altitude, then Fix 2 cannot be expected to function against the seven tracks and 98 targets listed under "LO" in Table 4-3.

The pairing of a "ringaround problem" sensor with a "clear" sensor in each of the Centers is fortuitous and somewhat puzzling. The traffic at the Centers should not be so very different for one sensor than the other. Yet IND had 119 instances of ringaround during 2 hours on a Monday afternoon and QWO, only 90 nmi to the east and underlying the same airway (J-80/110) had none.

Of the ringaround reports listed in Table 4-3, those from ZID and ZLA are expected to reach the Plan View Display (PVD) which is used to present the air traffic picture to the controller. Adaptation at ZJX is such that the ringaround targets are associated with supplementary sensors, i.e., a sensor which is essentially used for backup purposes.

Nevertheless, it may be worthwhile to eliminate ringaround at the ZJX sites. With the VAD and NEN sensors adapted as shown in Figure 4-1, the earth's curvature blocks off low altitude airspace for each sensor. Calculations indicate that aircraft within the 32 nmi square near VAD will not be seen if they are within 4,000 feet of the terrain. A similar situation is true for aircraft near NEN.

If, for instance, ringaround can be eliminated at the VAD sensor then ZJX may wish to adapt the VAD sensor for airspace near it.

### 4.1.2 The Data Base, Splits

The program Beacon False Target Analysis (BFTA) is used to determine splits on the tapes described in Table 4-1. Relevant documentation for this program is: (1) Functional Specification, FAA-4106-P-1 (June 11, 1976), (2) User's Manual, FAA-4306-P (April 30, 1976), and (3) Subprogram Design Logic, FAA-4206-1. The number of split targets so determined varied from 213 at IND to 1279 at CDC.

The number of split targets noted as determined by BFTA varied with the site from 213 (IND) to 1279 (CDC).

Table 4-3
Data Base, Ringaround

| Center | Sensor | Tracks with Ringaround Hi Alt. | Lo Alt. | Ringaround Reports Hi | Lo | Spare Bit Range | Spare Bit Alt. | Spare Bit Count |
|---|---|---|---|---|---|---|---|---|
| ZID | IND | 6 | 2 | 97 | 22 | 11 | 21,000 | 315 |
| | QWO | 0 | 0 | 0 | 0 | - | - | - |
| ZJX | NEN | 1 | 1 | 11 | 11 | 10½ | 19,000 | 200 |
| | VAD | 5 | 1 | 80 | 04 | 11 | 30,000 | |
| ZLA | CDC | 0 | 0 | 0 | 0 | - | - | |
| | QAS | 4 | 3 | 153 | 61 | 28 | 8,300 | 1730 |
| Totals | | 16 | 7 | 341 | 98 | | | 2,245 |

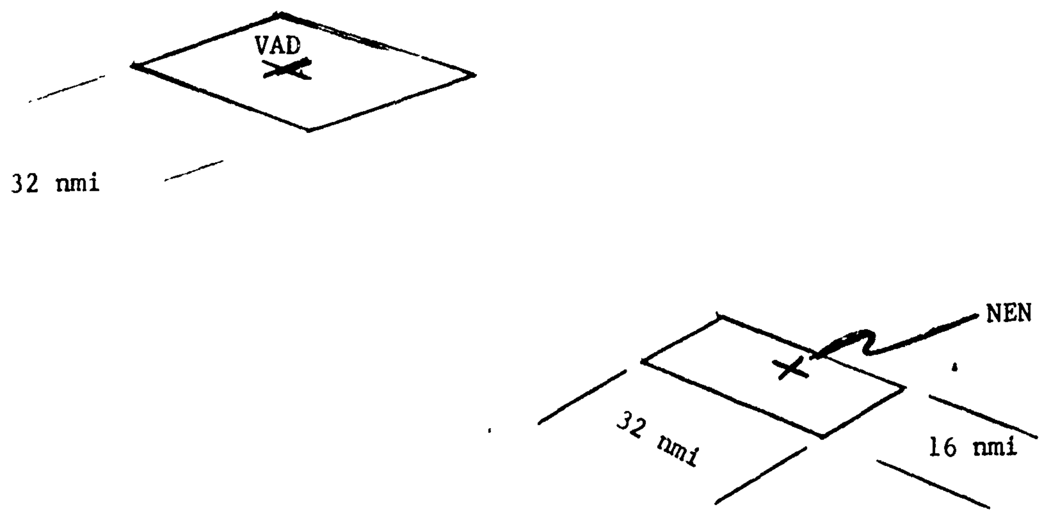



Figure 4-1 - In a square 32 nmi on a side near the VAD sensor, the more distant sensor NEN is ordinarily used for target detection. Similarly in a rectangle 32 nmi by 16 nmi near the NEN sensor, the VAD sensor is ordinarily used. The distance between VAD and NEN is 79 nmi.

Table 4-5
Data Base, Splits

| Center | Sensor | Total Splits | Time Analyzed | | Splits Analyzed | Percentage (split/discrete beacon) |
|---|---|---|---|---|---|---|
| ZID | IND | 213 | 2200Z | 2300Z | 112 | 0.32% |
| | QWO | 774 | 2200Z | 2300Z | 203 | 0.63% |
| ZJX | NEN | 433 | 1200Z | 1300Z | 119 | 0.70% |
| | VAD | 621 | 1200Z | 1300Z | 236 | 1.15% |
| ZLA | CDC | 1279 | 1840Z | 1900Z | 135 | 2.24% |
| | QAS | 1174 | 1840Z | 1900Z | 147 | 2.08% |

Not all of the targets available from the fix data base were used in analyzing the effectiveness of the anti-split (Fix 6). Reasonable time samples were taken from each tape with split counts as shown in Table 4-5.

The column in Table 4-5 labelled "Percentage" is the probability of a given target being a split target at each of the three sites.

### 4.1.3 The Data Base, Reflections

The reflected category of false target reports is used for balancing purposes. A reflected target is a false target report that is neither a split nor a ringaround. All reflected targets are matched to true targets in Mode 3/A and, if altitude is available, in altitude.

If target detection is 100% then each reflected target is associated with a true target. The target pair defines a reflecting surface. Figure 3-4 on page 23 describes the reflection geometry further.

Although every reflected pair defines a reflector, it is not in general possible to determine the presence of a physical reflector corresponding to the range and orientation given there.

Examination of the tapes from ZID, ZJX, and ZLA gave the number of reflections shown in Table 4-6. Of the total of 226 reflections from these Centers, only 10 could reasonably be associated with a reflector.

By this is meant that the numbers corresponding to RR, ΘR, and ΘF of equations 3-1 were widely scattered. The apparent reflection could be due to:

(1) Temporary reflectors like:

- 1.1 Large tail surface of aircraft if the sensor is near an airport (IND)
- 1.2 Atmospheric ducting

Alternately, the apparent reflectors could be non physical. A code change of a transponder as the transponder operator switches through a previously assigned code will result in an apparent reflection.

Because of the paucity of data on physical reflectors from ZID, ZJX, and ZLA, a request was made of ZNY to provide a tape from the NYC sensor. This sensor is located near JFK airport close to New York City and it was hoped that a significant number of physical reflectors would be found at this site.

Three reflectors were found from the inspection of the NYC tape which could reasonably be associated with physical objects. Two others were found where either (1) identification was uncertain or (2) the number of reflected targets was judged too small for including them in tests of reflector in the algorithm.

Table 4-6

Reflection Data from Four Air Route Traffic Control Centers

| Center | Sensor | Reflections | Reflectors | Reflections Associated w/reflectors |
|---|---|---|---|---|
| ZID | IND | 11 | 0 | 0 |
| | QWO | 7 | 0 | 0 |
| ZJX | NEN | 12 | 0 | 0 |
| | VAD | 39 | 1 | 10 |
| ZLA | CDC | 12 | 0 | 0 |
| | QAS | 145 | 0 | 0 |
| ZNY | NYC | 290 | 3 | 48 |

The reflection counts shown in Table 4-6 are those transmitted by the Common Digitizer to the Data Receiver Group at the Air Route Traffic Control Center. Due to the multiple coverage used in NAS Stage A only about half of those listed will reach the Plan View Display and the controllers. The other half are usually discarded. They would be available in case of failure of one of the preferred sensors.

Data concerning the reflector found near VAD and the three reflectors found near NYC are given in Table 4-7. It is notable that the bearing of the reflectors can be defined fairly narrowly, none had a false report more than 12 ACP from the assumed bearing and some had all reports within 4 ACP of the assumed bearing.

### 4.1.4 Model Data Base

Timing estimates will be required before a decision can be made concerning national implementation of proposed algorithms.

Formulas for timing estimates have been derived jointly with Computer Sciences Corporation and the MITRE Corporation by this Service. These formulas appear for each algorithm in Section 6 for the algorithm as it would be implemented. In this subsection the quantities to be used with the formulas are derived. Numerical evaluation of these formulas requires estimates of various parameters. These estimates have been made for two models, named Model A and Model D, intended to represent an ARTCC with 9020A equipment and one with 9020D equipment.

The values of the parameters are shown in Table 4-8. They are as follows:

(2) Number of sensors. Average from long range radar counts given in Controller Chart Supplement Section 9, Air Route and Airport Surveillance Radar Facilities (October 11, 1977) for the various 9020A ARTCC's and 9020D ARTCC's.

(3), (4), and (5) Discrete Target Rate. These numbers are taken from Appendix A of NAS Configuration Control Management Document, NAS-MD-318 (August 15, 1974).

(6) Tracks, From NAS-MD-318

(7) Different Discrete Target per sensor. The entry in column 3 is multiplied by the time of revolution of the sensor (10 seconds), and divided by the entry in column 2.

(8) Split altitude RSB's. These average two per sensor from the observation that one half of the sensors have ringaround problems (suggested by the data of Table 4-3) and that each of these problem sensors will require adapting four RSB's.

(9) Spare Bit Set. From Data Counts reported in Table 4-3.

Table 4-7

Characteristics of Reflectors

1.1 Reflector at VAD

| | |
|---|---|
| Range: | 0.5289 nmi |
| Bearing: | 2678 ± 5 ACP |
| Orientation: | 3235 ACP |

2. Reflectors at NYC

2.1 World Trade Center

| | |
|---|---|
| Range: | 11.068 nmi |
| Bearing: | 95 ± 4 ACP |
| Orientation: | 2376 |

2.2 Apartment Building

| | |
|---|---|
| Range: | 0.667 nmi |
| Bearing: | 95 ± 4 ACP |
| Orientation: | 1236 ACP |

2.3 Cargo Hangar

| | |
|---|---|
| Range: | 1.656 nmi |
| Bearing: | 2883 ± 12 ACP |
| Orientation: | 1732 ACP |

Table 4-8
Quantities which define Models A and D

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| | Number of Sensors | Disrcrete Target Rate (per second) from CD | Before sel rej | After sel rej | Tracks | Different Discrete Targets (per sensor) | Split Alt. RSB's | Spare Bit Set (per sec) |
| Model A | 6 | 67 | 50 | 24 | 222 | 112 | 12 | 0.41 |
| Model D | 7 | 136 | 101 | 48 | 444 | 194 | 14 | 0.84 |

| | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|
| | Reports in Split Alt. RSB's (per sec) | Targets in Problem Area (per sec) | Targets on Problem Bearing (per sec) | Entries no suppress Table | High Alt. Reports in Split Alt. RSB' (per sec) |
| Model A | 4.5 | 0.93 | 0.26 | 4 | 2.2 |
| Model D | 10.6 | 2.4 | 0.53 | 4 | 5.3 |

| | 15 | 16 | 17 | 18 |
|---|---|---|---|---|
| | Uncorrelated Targets chained for display | Ringaround Rate (per sec) | Split Rate (per sec) | Reflection Rate (per sec) |
| Model A | 1.8 | .06 | .19 | .03 |
| Model D | 3.6 | .14 | .39 | .06 |

(10) Reports in Split altitude RSB's. Calculated from the counts of discrete target reports within 12-3/4 nmi of the following sensors: IND, NEN, QAS, and from those within 18 nmi of VAD. The counts are normalized to the area of a radar sort box (256 sq nmi) and also normalized in proportion with the target counts of column 3 to the total counts observed in Table 4-1.

(11) Targets in Problem Area. At NYC it was found that the targets responsible for reflected reports were confined to a sector 30° in azimuth. We assume one reflector per ARTCC so that the rates in column 11 are 1/6 (1/7 for Model D) the rates in column 3 and 1/12 of this quantity (30°/360° = 1/12).

(12) Targets on Problem Bearing. The problem bearing can be defined, on average, to 8 ACP = 0.70°. The entry in column 12 is that in column 3 multiplied by 16/4096.

(13) Entries in no suppress table. This is the number of entries to assure that quasi discrete codes are properly treated. Arbitrarily set at four.

(14) High Altitude Reports in Split altitude RSB's. Arbitrarily set at one half the entry in column 10.

(15) Uncorrelated targets chained for display. The time of sensor revolution (10 sec) multiplied by the rate after selective rejection (column 5) less the number of tracks.

(16), (17), and (18) Ringaround, Split and Reflection Rates. From the rates observed as computed from the data of Tables 4-1, 4-3, 4-5, and 4-6 and normalized to the discrete target rates of column 3.

## 4.2 Hand Analysis

For each algorithm the problem targets which it is designed to address were sampled. Since evaluation must be quantitative, efforts were made to assure that the samples were representative of the data base.

Each fix required separate handling and further details on the manner in which the analysis was performed will be found in the appropriate subsection of Section 5.

## 4.3 Machine Analysis

This is an ambitious undertaking in which an Air Route Traffic Control Center is reproduced at the en route System Support Facility. The data base consisting of a simulation tape prepared by the RADCON program is played through the reproduced ARTCC and a list of target reports is taped.

The upper part of Figure 4-2 shows diagramatically how two Sim tapes, originally prepared from CD tapes, are played through a truncated NAS en route system. In the figure the en route software is skeletonized into the RIN subprogram and the RTG subprogram.

A tape, indexed as 140B in the figure, consists of all target reports in the Radar Data Table (RT) which have in effect been processed by RTG. The indexed number, 140, has no particular meaning in this case. It is essentially like the numbers in "IBM-360" or in "Oldsmobile - 88." The B stands for baseline.

Subsequent to the preparation of the 140B tape, the ARTCC is restructured with an algorithm patched onto subprogram RIN or subprogram RTG as appropriate. The simulation tapes are now played through the modified system and a pair of tapes prepared. These are indexed as 85 and 140M in the middle part of Figure 4-2.

The algorithms were patched so that potential false target reports are culled from the system and into the 85 tapes. This means that the 4470 code is not directly applicable to the algorithms as coded. It also means that Fix 2 as tested differs from the concept of Fix 2 in that the tested fix discards targets and the concept fix merely shifts them to the "supplementary" category. See Figure 3-2 on page 21.

Assuming a perfect system, including a perfect algorithm, tape 140B contains all the original target reports, tape 85 contains the false target reports and tape 140M contains the "true" target reports.

Next the Data Analysis and Reduction Tool (DART) is used. The targets on the simulation tape which have been determined to be false are listed on cards. DART compares the targets on tapes 140B, 140M, and 85 and those on the cards. Assuming all is well then a given target report can appear in one of four possible configurations:

| | 140B | 140M | 85 | FTL |
|---|---|---|---|---|
| (1) | Yes | Yes | No | Yes |
| (2) | Yes | No | Yes | No |
| (3) | Yes | Yes | No | No |
| (4) | Yes | No | Yes | No |

The configurations correspond to interpretations as follows:

(1) False target report not suppressed by the algorithm under test.

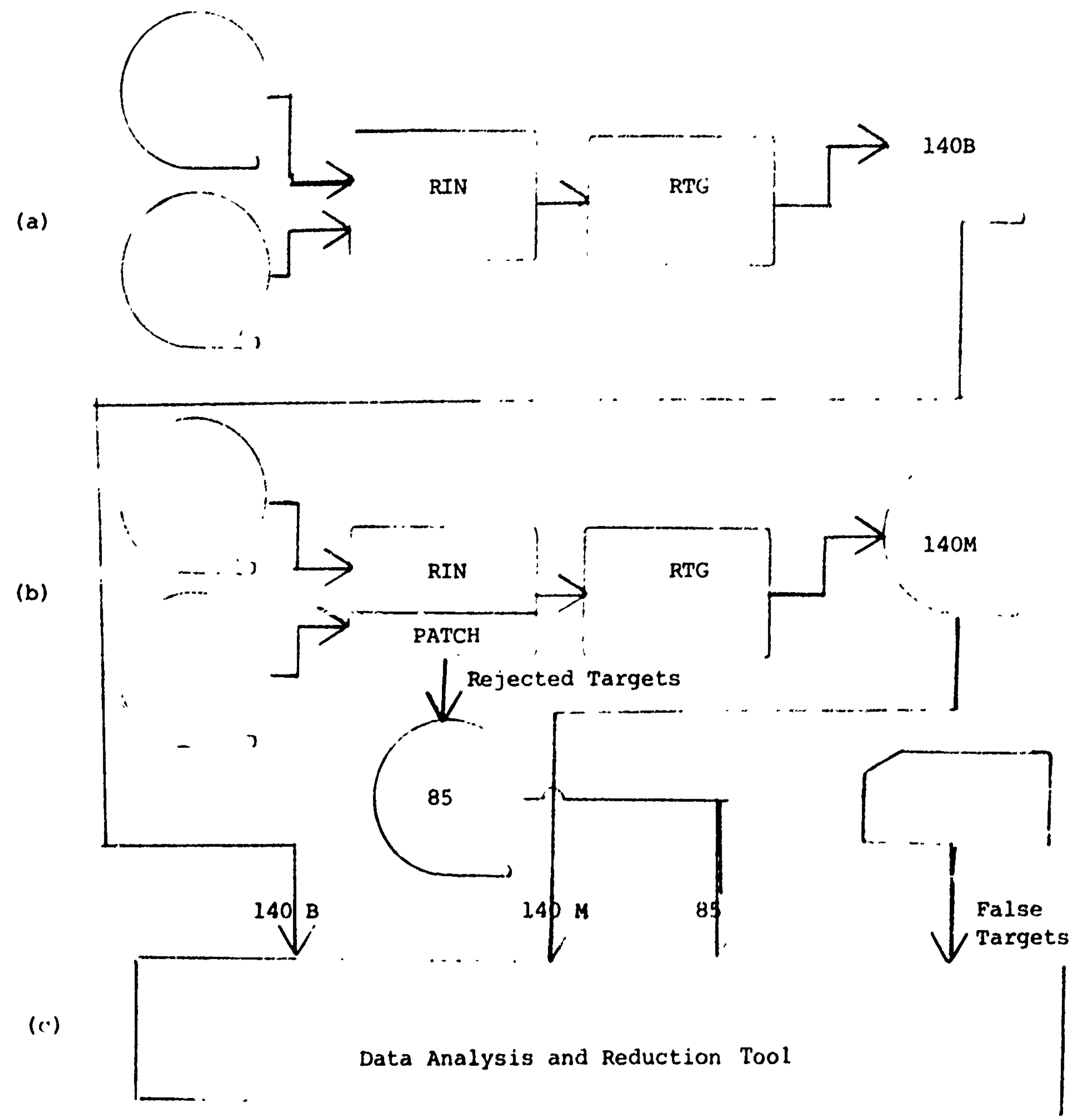



Figure 4-2 - Steps in machine analysis of algorithm effectiveness. Targets on Sim tape are played through baseline System and 140B tape is prepared (a). Same targets are played through modified System and rejected targets are recorded on the 85 tape and "true" targets on the 140M tape (b). Finally, the Data Analysis and Reduction Tool (c) compares how target reports appear on the 140B, 140M, and 85 tapes with the False targets previously recorded on cards. Ideally targets are classified as: (1) 1101 false target not suppressed, (2) 1011 false target suppressed, (3) 1100 true target not suppressed, and (4) 1010 true target "suppressed".

(2) False target report suppressed by the algorithm under test.
(3) True target report not suppressed by the algorithm under test.
(4) True target report suppressed by the algorithm under test.

Target reports in category 4 must be applied to Fix 2 with care. As coded, Fix 2 sends high altitude reports in affected RSB's to the oblivion of the 85 tapes. In practice these reports will be declared supplemental and will be available for track correlation. They will not ordinarily be available for display.

In addition to the four categories of target reports just described there are seven others which should not include any target reports, but which in practice contain reports.

These are in three groups as follows:

(A) Targets on baseline run, but not on modified run:

| Category | 140B | 140M | 85 | FTL | |
|---|---|---|---|---|---|
| (5) | Yes | No | No | Yes | (1001) |
| (6) | Yes | No | No | No | (1000) |

A target report in category five is described as a false report lost, one in category six is described as a true report lost.

(B) Targets on modified run, but not on baseline run:

| Category | 140B | 140M | 85 | FTL | |
|---|---|---|---|---|---|
| (7) | No | Yes | No | Yes | (0101) |
| (8) | No | No | Yes | Yes | (0011) |
| (9) | No | Yes | No | No | (0100) |
| (10) | No | No | Yes | No | (0010) |

These are targets which appear to be added to the system as a result of the algorithm action.

Finally there are cases where the target listed on the cards simply does not show up at all:

(C) Unaccounted False Target Reports

| Category | 140B | 140M | 85 | FTL | |
|---|---|---|---|---|---|
| (11) | No | No | No | Yes | (0001) |

The flow chart for determining into which of the eleven categories of target reports one sends each report is shown in Figure B-2 of Appendix B. Appendix B is that section of the contractor's report which concerns this analysis.

## 5. EFFECTIVENESS OF FIXES

The effectiveness of each of the fixes is estimated in this section. Generally, effectiveness is hand calculated. This calculation is based on a knowledge of what the fix is expected to do under any circumstances and the circumstances are those defined by the data base discussed in Section 4.

For each of the fixes, Fix 5 excepted, a machine calculation of effectiveness was made as discussed in subsection 4.3. The results of the machine calculation were successful only in the case of Fix 2. However, for archival purposes, the results for other algorithms are generally included in this section.

### 5.1 Effectiveness of Fix 1

As pointed out previously (subsection 3.1) work on this fix was not carried correctly through coding. Hence, only hand analysis of Fix 1 is reported. For an example of this analysis, see Appendix C.

#### 5.1.1 Fix 1 at IND

With the parameters for setting the spare bit described in Table 4.3, namely Range = 11 nmi altitude = FL210, this algorithm will eliminate 106 of the 119 ringaround targets which were discovered. Eight remaining ringaround reports have ranges greater than 11 nmi and five have no altitude data.

The effectiveness of Fix 1 at IND is thus estimated to be 89%.

#### 5.1.2 Fix 1 at QAS

With the parameter settings for the spare bit described in Table 4.3, namely Range = 28 nmi and altitude = FL083, the algorithm is expected to eliminate 143 of the 214 reported false ringaround targets.

The effectiveness of algorithm 1 at QAS is thus estimated to be 67%.

### 5.2 Effectiveness of Fix 2

This fix was analyzed by hand and by machine. It is the single instance in which the two analyses support each other well.

#### 5.2.1 Fix 2 at ZID

##### 5.2.1.1 Fix 2 at ZID, hand analysis

Five aircraft which were involved in a ringaround situation were followed using hand analysis. They are identified by their beacon codes. Each aircraft was followed within a range of 30 nmi of the IND sensor using data from both the IND sensor and the QWO sensor. QWO is located near London, OH about 129 nmi to the East of the IND sensor. The date of observation is in all cases September 20, 1976.

(1) An aircraft squawking 1671 at FL311 was observed with both IND and QWO sensors from 2132Z until 2136Z. During this time frame it was within 30 nmi of the IND sensor. The following imperfections were observed:

| IND | QWO |
|---|---|
| 2 misses | perfect transmission |
| 1 extra target | |

(2) An aircraft squawking 2771 at FL350 was observed by the IND and QWO sensors between 2157Z and 2203Z. It was within 30 nmi of IND during this time frame. The following discrepancies are noted:

| IND | QWO |
|---|---|
| 10 misses | no misses |
| 37 extra | no extra |

(3) An aircraft squawking 7257 at FL368 was observed by the two sensors between 2140Z and 2147Z. It was within 30 nmi of the IND sensor during this time frame. The following discrepancies from each sensor are noted:

| IND | QWO |
|---|---|
| 13 misses (2 without Mode C) | no misses |
| 29 extra | 2 extra (split) |

(4) An aircraft squawking 3072 at FL390 was observed by the two sensors from 2155Z to 2202Z while it was within 30 nmi of the IND sensor with the following discrepancies from each sensor:

| IND | QWO |
|---|---|
| 21 misses | no misses |
| 3 extra (1 without Mode C) | 2 extra (split) |

(5) An aircraft squawking 6246 at FL230 was observed between 2243Z and 2250Z when it was within 30 nmi of the IND sensor with the following discrepancies from each sensor:

| IND | QWO |
|---|---|
| 11 misses (2 without Mode C) | 8 misses |
| 21 extra | no extra |

From the data in the sample it is concluded that QWO should be the preferred sensor for aircraft with altitudes above FL230 within 30 nmi of the IND sensor. It is further concluded that algorithm 2 will be an effective fix against ringaround at the IND sensor. Except for five reports all ringaround reports had Mode C data and would be eliminated by algorithm 2.

5.2.1.2 Fix at ZID, machine analysis

As described in subsection 4.3 target reports from ZID constructed with ZID adaptation and with sensors IND and QWO operative were recorded with and without the test version of Fix 2 patched into subprogram RIN.

The affected RSB's are the ones containing IND sensor and its eight nearest neighbors. The split levels associated with the algorithm are FL085 and FL235. The time period analyzed is from 2143Z to 2306Z.

The following results were observed with the FL085 split level:

| | |
|---|---|
| False reports suppressed | 94 |
| False reports not suppressed | 211 |
| True reports "suppressed" | 3,005 |
| True reports not suppressed | 82,578 |
| Sum | 85,880 |

The word "suppressed" in the third line of this table is set in quotation marks to indicate that suppression occurs only in the test version of the algorithm. In operation the "suppressed" reports would be treated as supplemental reports.

Note that the test algorithm suppressed 31% of the target reports which were recorded onto false target cards and also showed up on both the baseline run and the test run. Most of these false target reports are of the split or reflection type and the algorithm ordinarily is not expected to function against these reports. Broken down into false target reports by type the results are:

| | suppressed | not suppressed |
|---|---|---|
| Ringaround | 81 | 4 |
| Reflections | 2 | 13 |
| Splits | 11 | 194 |
| Sums | 94 | 211 |

Against ringaround at ZID with a split altitude at FL085 the algorithm is 95.2% effective (81 out of 85).

The numbers thus far presented in this subsection should be used with caution. Some target reports showed up on the baseline run which were not on the algorithm run, some on the algorithm run which were not on the baseline run and some did not show up at all. The appropriate numbers are as follows:

Reports on baseline run,but not algorithm run. The index numbers in parentheses refer to the categories of subsection 4.3.

| | | |
|---|---|---|
| (5) | Reports on false target list | 7 |
| (6) | Reports not on false target list | 6,849 |
| | Sum | 6,856 |

Reports on algorithm run,but not on baseline run.

| | | | |
|---|---|---|---|
| (7) | False | (0101) | 5 |
| (8) | False | (0011) | 0 |
| (9) | Not False | (0100) | 11,792 |
| (10) | Not False | (0010) | 72 |
| | Sum | | 11,869 |

Further, 75 target reports on the false target list did not show up on either run.

The algorithm was run with FL235 as the split altitude with the following results (reports on both runs)

| | |
|---|---|
| False reports suppressed | 93 |
| False reports not suppressed | 206 |
| True reports "suppressed" | 2,260 |
| True reports not suppressed | 83,042 |
| Sum | 85,601 |

Once again few non-ringaround targets are suppressed:

| | suppressed | not suppressed |
|---|---|---|
| Ringaround | 82 | 3 |
| Reflections | 2 | 13 |
| Splits | 9 | 190 |
| Sum | 93 | 206 |

Against ringaround at ZID with a split altitude at FL235 the algorithm is 96% effective (82 out of 85).

As with the high altitude version of the algorithms some targets reports showed up only on the baseline run.

Baseline, not algorithm

| | | |
|---|---|---|
| (5) | Targets on false target list | 12 |
| (6) | Targets not on false target list | 7,131 |
| | Sum | 7,143 |

And some showed up only on the algorithm run.

Algorithm, not baseline

| | | | |
|---|---|---|---|
| (7) | False | (0101) | 5 |
| (8) | False | (0011) | 0 |
| (9) | Not False | (0100) | 5,753 |
| (10) | Not False | (0010) | 46 |
| | Sum | | 5,805 |

Further, 80 targets reports on the false target list did not show up on on either run.

The numbers given in this subsection are reproduced in Table 5.1. They are presented to show the overall consistency of the baseline run and the two algorithm runs.

5.2.1.3 Fix 2 at ZID, summary of analyses

The results of the hand analysis of subsection 5.2.1.1 and of the machine analysis of subsection 5.2.1.2 are consistent and show that algorithm 2 should be effective against ringaround at the IND radar. They form a significant base for the recommendation of Section 8 that Fix 2 be adopted as a fix against false target reports.

5.2.2 Fix 2 at ZJX and ZJX (V)

Fix 2 was analyzed by hand using the ZJX data base and the ZJX adaptation. It was also analyzed by machine using a somewhat different adaptation.

5.2.2.1 Fix 2 at ZJX

The Jacksonville ARTCC adapts RSB's so that the local sensor is secondary in its immediate geographical area. For example, sensor NEN located near White House, FL is located in RSB 516. The preferred sensor for this RSB and for RSB 515 adjacent is the VAD radar. VAD is located at Valdosta, GA located 79 nmi to the northwest of NEN. If algorithm 2 is implemented at ZJX its advantage is not elimination of ringaround, but rather the advantage which the local sensor has in detecting low altitude targets.

Calculations along the lines of subsection 6.2.1 suggest that the lowest feasible split altitude at NEN and VAD is 4,000 feet. Inspecting Common Digitizer Record tapes from the Jacksonville Center for the period 1047Z to 1321Z for August 20, 1976, it is noted that one may expect an additional 1900 preferred targets at NEN and 26 targets at VAD. This is an estimate using target counts of targets within 12.75 nmi of the NEN and 18 nmi of VAD. These radii correspond to an area equivalent to that to two RSB's for NEN and four RSB's for VAD. In effect a round geometry, compatible with the Common Digitizer geometry has been substituted for the square geometry of the RSB system in use in the NAS.

5.2.2.2 Fix 2 at ZJX (V)

As discussed in subsection 3.1.1, ZJX treats the ringaround problem by assigning the RSB's near the VAD radar to the NEN sensor and vice versa. The effectiveness of Algorithm 2 at ZJX(V) was determined. By ZJX(V) is meant the ARTCC adaptation where the RSB's local to the VAD radar are assigned to VAD and those near NEN are assigned to NEN.

The following results were observed with the split altitude of 4,500 feet. The time period is from 1053Z to 1221Z.

TABLE 5-1

Results of Machine Analysis of Algorithm 2 at ZID

CD Record Tape N928 from 2143Z to 2306Z

| | Split altitude is FL063 | | Split altitude is FL235 | |
|---|---|---|---|---|
| (1) False reports suppressed | 94 | | 93 | |
| (2) False reports not suppressed | 211 | | 206 | |
| (3) True reports "suppressed" | 3,005 | | 2,260 | |
| (4) True reports not suppressed | 82,578 | | 83,042 | |
| Sums | | 85,880 | | 85,101 |
| Reports on baseline, not algorithm | | 6,857 | | 7,143 |
| Reports on Algorithm, not baseline | | 11,869 | | 5,805 |
| Sums | | 104,606 | | 98,549 |

| | | |
|---|---|---|
| False reports suppressed | 114 | |
| False reports not suppressed | 184 | |
| True reports "suppressed" | 3,893 | |
| True reports not suppressed | 76,278 | |
| Sum | | 80,469 |

The algorithm works well against ringaround, but is essentially ineffective against reflections and splits.

| | suppressed | not suppressed |
|---|---|---|
| Ringaround | 87 | 2 |
| Reflections | 17 | 21 |
| Splits | 10 | 161 |
| Sums | 114 | 184 |

Against ringaround at ZJX(V) with a split altitude of FL045 the algorithm is 98% effective (87 out of 89).

However there are some imperfections in the analysis. Some target reports appeared on the baseline run, but not on the algorithm run:

Baseline, not algorithm

| | | |
|---|---|---|
| (5) Reports on false target list | 11 | |
| (6) Reports not on false target list | 8,678 | |
| Sum | | 8,689 |

Target reports also appeared on the algorithm run, but not the baseline run. The breakdown is as follows:

Algorithm, not baseline

| | | | |
|---|---|---|---|
| (7) False | (0101) | 2 | |
| (8) False | (0011) | 0 | |
| (9) Not False | (0100) | 8,678 | |
| (10) Not False | (0010) | 90 | |
| Sum | | | 8,770 |

Further, 172 targets on the false target list appeared on neither the baseline run nor the algorithm run.

Letting the split altitude be FL235 similar results as those at FL045 were obtained.

| | | |
|---|---|---|
| False reports suppressed | 110 | |
| False reports not suppressed | 186 | |
| True reports "suppressed" | 2,040 | |
| True reports not suppressed | 78,193 | |
| Sum | | 80,529 |

The algorithm works well against ringaround , but poorly against other type of false targets:

| | suppressed | | not suppressed | |
|---|---|---|---|---|
| Ringaround | 84 | | 5 | |
| Reflections | 17 | | 19 | |
| Splits | 9 | | 162 | |
| Sums | | 110 | | 186 |

Against ringaround at ZJX(V) with a split altitude of FL235 the algorithm is 94% effective (84 out of 89).

As at ZID, the analysis is not 100% perfect, some reports appeared on the baseline run and not the algorithm run:

Baseline, not algorithm

| | | |
|---|---|---|
| Reports on false target list | 13 | |
| Reports not on false target list | 8,617 | |
| Sum | | 8,630 |

And some appeared on the algorithm run and not the baseline run.

Algorithm, not baseline

| | | | | |
|---|---|---|---|---|
| (7) | False | (0101) | 1 | |
| (8) | False | (0011) | 0 | |
| (9) | Not False | (0100) | 5,996 | |
| (10) | Not False | (0010) | 54 | |
| | Sum | | | 6,051 |

Further 183 target reports on the false target list appeared on neither the algorithm run nor the baseline run.

Table 5-2 summarizes the counts for the situation at ZJX(V). The numbers show that the fix is expected to be about 95% effective at ZJX(V).

### 5.2.3 Fix 2 at ZLA

Fix 2 was analyzed by hand and by machine with the ZLA data base and with the ZLA adaptation.

## TABLE 5-2

**Results of Analysis of Fix 2 at ZJX(V)**

**CD Record Tape S181 from 1053Z to 1231Z**

| | Split altitude is 4 500 feet | | Split altitude is FL235 | |
|---|---|---|---|---|
| **Ringaround suppressed** | 87 | | 84 | |
| **Ringaround not suppressed** | 2 | | 5 | |
| **Other false reports suppressed** | 27 | | 26 | |
| **Other false reports not suppressed** | 182 | | 181 | |
| **True report "suppressed** | 3,893 | | 2,040 | |
| **True reports not suppressed** | 76,278 | | 78,193 | |
| **Sum** | | 80,689 | | 80,529 |
| **Reports on baseline run, not on algorithm run** | 8,689 | | 8,630 | |
| **Reports on algorithm run, not on baseline run** | 8,770 | | 6,051 | |
| **Sum** | | 97,928 | | 95,210 |

5.2.3.1 Fix 2 at ZLA, hand analysis

Eight aircraft which were involved in a ringaround situation at ZLA on November 1, 1976, were followed. They are identified by their beacon codes. Each aircraft was followed within a range of 30 nmi of the QAS sensor. QAS is located near Las Vegas, NV. Each aircraft was also followed with the CDC sensor located near Cedar City, UT. CDC is located approximately 151 nmi east of QAS. All extra QAS reports had Mode C data except as noted.

(1) An aircraft squawking 2323 was descending in the Las Vegas, NV area within 30 nmi of QAS. Its altitude varied from FL177 to FL060 as time varied from 1823Z to 1830Z. The following results were observed at each sensor.

| QAS | CDC |
|---|---|
| 1 extra target | 1 extra target |
| 3 misses | 18 misses |

From 1830Z to 1834Z the aircraft was below FL060. It was not observed by CDC during this time period. QAS observed the target, missing twice and experiencing one split.

(2) An aircraft squawking 0126 was within 25 nmi of QAS during the time frame 1958Z to 2009Z. Its altitude was FL113. The following discrepancies were noted from QAS and from CDC.

| QAS | CDC |
|---|---|
| 15 extra (2 without Mode C) | no reports |

Aircraft range from CDC after 2006Z was greater than 144 nmi.

(3) An aircraft squawking 6451 at an altitude from FL158 to FL085 was observed between 1824Z and 1835Z during which time it was within 30 nmi of the QAS sensor. The following discrepancies were observed:

| QAS | CDC |
|---|---|
| 2 extra | no extra |
| no misses | 38 misses |

(4) An aircraft squawking 3312 descended from FL195 to FL180 approaching Nellis AFB. It was observed from 1923Z during which time it was within 30 nmi of QAS. The following discrepancies were noted:

| QAS | CDC |
|---|---|
| 24 extra (5 without Mode C) | no extra |
| 10 misses | 28 misses between FL207 and FL128 and 24 misses below FL065 |

(5) An aircraft squawking 0417 descending from FL085 to FL015 approached Nellis AFB. It was within 30 nmi of QAS during the time period 1858Z to 1905Z. The following discrepancies were observed:

| QAS | CDC |
|---|---|
| 10 extra (2 without Mode C) | no extra |
| 2 misses | 38 misses |

From examples 1 through 5, it appears that fix 2 will be ineffective at ZLA against ringaround reports if the associated target below FL160.

(6) An aircraft squawking 3302 was traveling West to East on J-92 passing South of QAS. Its altitude was FL410. It was observed during the period 2000Z to 2007Z during which time it was within 30 nmi of QAS. The following results were observed:

| QAS | CDC |
|---|---|
| 47 extra (7 without Mode C) | no extra |
| no misses | no misses |

(7) An aircraft squawking 2527 at an altitude of FL311 was observed between 1845Z and 1853Z during which time it was within 30 nmi of the QAS sensor. The following imperfections were observed:

| QAS | CDC |
|---|---|
| 62 extra (12 without Mode C) | 1 extra (split) |

Neither sensor had any misses during this time period.

(8) An aircraft squawking 2560 at FL350 was observed between 1846Z and 1852Z during which time it was within 30 nmi of the QAS sensor. The following imperfections were observed:

| QAS | CDC |
|---|---|
| 7 extra (ringaround) | 1 extra (split) |

Algorithm 2 will not be effective against false targets where the altitude of these targets is FL185 or less.

From examples 6 through 8 it appears that Fix 2 will be effective against ringaround if the associated target is above FL310. On a percentage basis effectiveness is 83%.

It is believed that a reasonable choice for the split level at QAS is FL235. This should eliminate about 80% of the false target reports in the high altitude sectors.

5.2.3.2 Fix 2 at ZLA, machine analysis

Fix 2 in the form of the algorithm described in subsection 3.2 was run at the System Support Facility with a modified ZLA adaptation. The modification consisted of operating only the QAS and CDC radars. The radar sort box (RSB) containing QAS and its eight nearest neighbors were adapted as split altitude RSB's. Split altitude was set at FL195 and at FL235. The time frame is from 1846Z to 2112Z on November 1, 1976.

With FL19' .. the split altitude, the following results were observed.

| | | |
|---|---|---|
| False reports suppressed | 108 | |
| False reports not suppressed | 206 | |
| True reports "suppressed" | 2,287 | |
| True reports not suppressed | 77,095 | |
| Sum | | 79,750 |

Fix 2 works well at ZLA low against ringaround, but poorly against other kinds of false targets:

| | suppressed | not suppressed |
|---|---|---|
| Ringaround | 88 | 54 |
| Reflections | 14 | 54 |
| Splits | 6 | 152 |
| Sum | 108 | 260 |

Against ringaround at ZLA Fix 2 is 62% effective (88 out of 142), with the split at an altitude of FL195.

However there are some imperfections in the analysis. Some target reports appeared on the baseline run, but not on the algorithm run.

Baseline, not algorithm

| | | |
|---|---|---|
| (5) Reports on false target list | 30 | |
| (6) Reports not on false target list | 7,889 | |
| Sum | | 7,919 |

Further some reports appeared on the algorithm run, but not on the baseline run:

Algorithm, not baseline

| | | | |
|---|---|---|---|
| (7) False Reports | (0101) | 5 | |
| (8) False Reports | (0011) | 15 | |
| (9) True Reports | (0100) | 5,353 | |
| (10) True Reports | (0010) | 53 | |
| Sum | | | 5,426 |

In addition there were 84 reports on the false target list which appeared on neither run with split altitude set at FL195.

At a split level of FL235 results were similar:

| | | |
|---|---|---|
| False reports suppressed | 87 | |
| False reports not suppressed | 183 | |
| True reports "suppressed" | 1,007 | |
| True reports not suppressed | 56,693 | |
| Sum | | 57,970 |

Ringaround target reports were handled fairly well, the others poorly:

| | suppressed | not suppressed |
|---|---|---|
| Ringaround | 74 | 41 |
| Reflections | 11 | 50 |
| Splits | 2 | 92 |
| Sum | 87 | 183 |

Against ringaround at ZLA algorithm 2 is 64% effective (74 out of 115) using a split altitude of FL235.

Imperfections in the analysis are measured by target report counts on the baseline run and not on the algorithm run.

Baseline, not algorithm

| | | |
|---|---|---|
| (5) Reports on false target list | 19 | |
| (6) Reports not on false target list | 4,675 | |
| Sum | | 4,694 |

Imperfections in the analysis may also be measured by target report counts on the algorithm run, but not on the baseline run:

Algorithm, not baseline

| | | | |
|---|---|---|---|
| (7) False Reports | (0101) | 2 | |
| (8) False Reports | (0011) | 15 | |
| (9) True Reports | (0100) | 2,474 | |
| (10) True Reports | (0010) | 21 | |
| Sum | | | 2,512 |

The quantities measured during the course of the machine analysis at ZLA are shown in Table 5-3.

The internal consistency of the numbers presented in this table is less than perfect. The quantities associated with the comparison with FL235 in particular are rather low.

#### 5.2.3.3 Fix 2 at ZLA, comparison of analyses

The analysis of this algorithm discussed in subsection 5.2.3.1 and the analysis discussed in subsection 5.2.3.2 are qualitatively consistent. They show that most high altitude ringaround reports will be suppressed (subsection 5.2.3.1) and that many of the ringaround type of false targets are from low altitudes. Overall efficiency against ringaround reports at the QAS radar is expected to be 64%. Against ringaround reports associated with targets above FL235 efficiency is estimated at 84%.

TABLE 5-3

Results of Machine Analysis of Fix 2 at ZLA

CD Record Tape K396 from 1846Z to 2112Z

| | Split altitude is 19,500 feet | | Split altitude is FL235 | |
|---|---|---|---|---|
| Ringaround suppressed | 88 | | 74 | |
| Ringaround not suppressed | 54 | | 41 | |
| Other false targets suppressed | 20 | | 13 | |
| Other false targets not suppressed | 206 | | 142 | |
| True targets "suppressed" | 2,287 | | 1,007 | |
| True targets not suppressed | 77,095 | | 56,693 | |
| Sum | | 79,750 | | 57,970 |
| Reports on baseline run, not on algorithm run | | 7,919 | | 4,694 |
| Reports on algorithm run, not on baseline run | | 5,426 | | 2,512 |
| Sum | | 93,095 | | 65,176 |

5.2.4 Expected effectiveness of Fix 2

Extrapolating from the data presented in the subsections immediately proceding it is expected that this fix will be comparitively effective in implementation. It has proven very effective at the radar sites situated in flat terrain (IND, NEN and VAD) and may be described as fairly effective at a site situated in mountainous terrain (QAS).

To be useful in general it requires double radar coverage of the airspace near the radar site experiencing the ringaround phenomenon. The question of such coverage is discussed in subsection 6.2.1.

## 5.3 Fix 3

This fix is expected to be effective against ten target reports associated with the VAD sensor at ZJX, and after allowance for RSB adaptation is taken into account, for one target report associated with NYC at ZNY. It is clearly not an algorithm with general usefulness.

Fix 3 can be used in the special case where a known reflector is responsible for conspicuous reflections. During the course of this study these conditions were found only near the radar at McCook, IL. If other sites are associated with reflection difficulties Fix 3 may be considered if (1) many reflections are along a given bearing and (2) a reflector can be associated with that bearing.

The CD record tape from McCook, IL, covering the time frame 1445Z to 1638Z on May 13, 1976, contains, according to a BFTA, 138 reflected target reports. Twenty-two of these 138 reports apparently are reflections from the John Hancock building and 37 are reflections are from the Sears Tower.

This analysis is merely a summary of the BFTA listing. Figure 5-1 shows the local geography and the geometry of the situation. Targets within the triangle ABC are the source of reflections. The problem bearings are shown as PB-1 and PB-2 in the figure.

Only one of the reflector reports could clearly be identified with an en route aircraft. It was at flight level 350. All of the others were at FL096 or below.

When run as a patch to the operational code neither the "A" or the "B" version of algorithm 3 suppressed any targets at ZJX.

When run as a patch to the operational code algorithm 3A suppressed seven targets at NYC which did not appear on the false target list and none which so appeared.

The problem with the machine analysis appears to be concerned with adaptation. None of the problem targets could be found visually on the Plan View Display and the track initiation required for this algorithm to function could not be made. This was a problem not foreseen when the algorithm was originally studied.

The target responsible for the false target report must be tracked and in the TK/TH Table if algorithm 3A is to be effective.

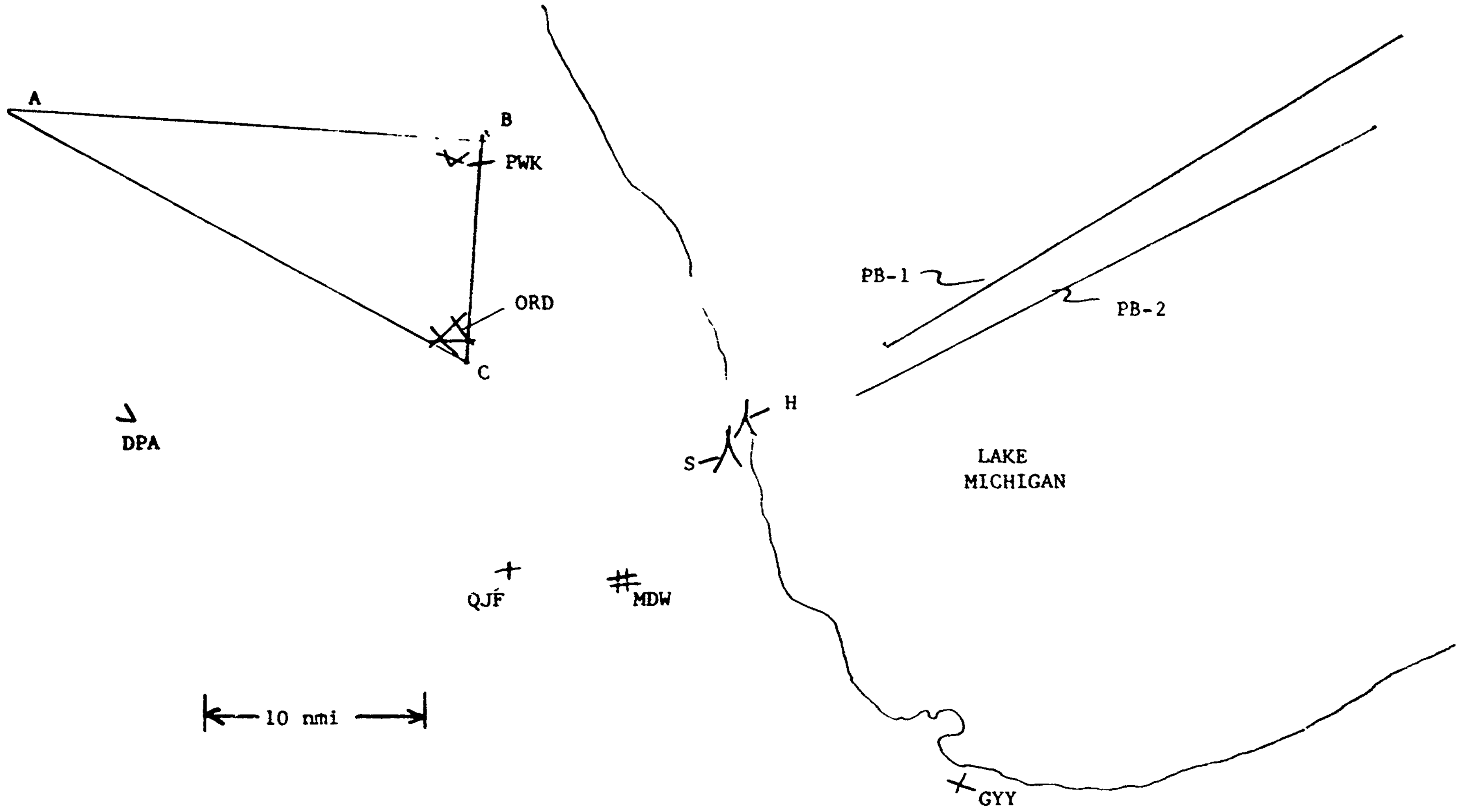



Figure 5-1 - Reflections near McCook, IL radar. Aircraft operating in the triangle marked ABC have been observed as reports reflected off the tall structures H and S along the straight lines PB-1 and PB-2. Symbols: DPA is Dupage County Airport, PWK is Pal Waukee Airport, ORD is Chicago O'Hare Airport, MDW is Midway Airport, GYY is Gary Airport, QJF is McCook radar. S is the Sears Tower and H is the Hancock Building.

It follows that Fix 3A will be effective only if (a) a reflector can be identified and (b) the targets which are reflected are within an area where they are tracked.

## 5.4 Fix 4

The effectiveness of this fix should approach 100% against reflections. However, its large potential error area is a drawback. See Section 6.4.

## 5.5 Fix 5

This fix was coded as an algorithm for testing, but was not in fact tested. The analysis of the effectiveness of the algorithm is given in section 6.2 of JWT and is summarized here in Table 5.4. For further information the reader should refer to JWT.

## 5.6 Fix 6 (against splits)

This fix was coded into the Radar Input Processing (RIN) Subprogram as a five target holding table. A split is to be declared if a match is found in Mode 3/A code, range (1/8 nmi), altitude (200 feet) and bearing. The bearing match is coded as 1½ nmi, that is the product of range and bearing difference (bearing difference measured in radian where radian = 2048 ACP) must be less than 1½ nmi.

Hand calculations show the effectiveness of this fix should vary upwards from 40% and should approach 100% if the bearing difference requirement is relaxed.

Hand calculations of Fix 6 are made by inspecting the BFTA list of split targets and selecting out those splits with range less than 100 nmi. The bearing difference of the two split targets is multiplied by the radar range of the more distant target. If the product is 978 nmi - ACP or greater then this split is considered not to be suppressed. If the product is less than 978 nmi - ACP then the fix should affect the split targets.

Machine calculations are puzzling and non-reproducible.

### 5.6.1 Fix 6 at ZID

#### 5.6.1.1 Fix 6 at ZID, hand analysis

Hand calculations were made from the target reports of the IND sensor and of the QWO sensor. The following results were obtained:

TABLE 5-4

Calculated effectiveness of using run length criteria against ringaround. After J.W. Thomas, FAA Report RD-77-12, IV (February 1978).

| Lower Limit of Run Length Accepted (ACP) | Upper Limit of Run Length Accepted (ACP) | True Reports Suppressed (%) | False Reports Suppressed (%) |
|---|---|---|---|
| 16 | 104 | 00 | 30 |
| 36 | 104 | 10 | 72 |

| | IND | QWO |
|---|---|---|
| Splits sampled | 44 | 41 |
| Splits suppressed | 37 | 34 |
| Ratio and standard deviation (%) | 84 ± 6 | 83 ± 6 |
| Maximum azimuth distance | 2.75 nmi | 2.12 nmi |

By maximum azimuth distance in the above table is meant that all split targets reports at IND lie within a beacon azimuth distance of 2.75 nmi one to another and that all split reports at QWO lie within an azimuth distance 2.12 nmi one to another. If the bearing match distance is raised to the larger number from 1-½ nmi then the efficiency of algorithm 6 in suppressing splits approaches 100%.

#### 5.6.1.2 Fix 6 at ZID, machine analysis

It does not appear that useful conclusions can be drawn from the ZID machine analysis. The numbers below are included here only for the sake of completeness.

The following results were obtained from separate runs:

| | Run 1 | Run 2 |
|---|---|---|
| False reports suppressed | 46 | 133 |
| False reports not suppressed | 258 | 173 |
| True reports suppressed | 101 | 256 |
| True reports not suppressed | 45,712 | 61,524 |

The results of the runs should be essentially identical. Run 1 was with the loop sim mode and run 2 with direct sim. Loop sim uses a 9020 duplex system and direct sim uses a 9020 triplex system.

### 5.6.2 Fix 6 at ZLA

#### 5.6.2.1 Fix 6 at ZLA, hand analysis

Hand calculations were made of the target reports from the QAS sensor and from the CDC sensor. The following results were obtained:

| | QAS | CDC |
|---|---|---|
| Splits sampled | 66 | 45 |
| Splits suppressed | 39 | 34 |
| Ratio and standard deviation (%) | 59 ± 6 | 76 ± 6 |
| Maximum azimuth distance | 5.2 nmi | 5.5 nmi |

#### 5.6.2.2 Fix 6 at ZLA, machine analysis

Useful conclusions cannot be drawn from the ZLA machine analysis.

### 5.6.3 Fix 6 at ZJX

#### 5.6.3.1 Fix 6 at ZJX, hand analysis

Hand calculations were made of the target reports from the NEN sensor and from the VAD sensor. The following results were obtained:

| | NEN | VAD |
|---|---|---|
| Splits sampled | 47 | 103 |
| Splits suppressed | 37 | 41 |
| Ratio and standard deviation (%) | 79 $\pm$ 6 | 40 $\pm$ 5 |
| Maximum azimuth distance | 2.0 nmi | 3.8 nmi |

#### 5.6.3.2 Fix 6 at ZJX, machine analysis

Only the loop sim type of run was made of Fix 6. The results reported here are highly suspect:

| | |
|---|---|
| False reports suppressed | 20 |
| False reports not suppressed | 277 |
| True reports suppressed | 51 |
| True reports not suppressed | 85,068 |

### 5.6.4 Overall effectiveness of Fix 6

Fix 6 is expected to be effective as quoted in subsections 5.6.1.1, 5.6.2.1, and 5.6.3.1. The machine calculations reported in subsections 5.6.1.2 and 5.6.3.2 are not used.

Further work on machine calculations to make them more reliable is proceeding. Effort is scheduled to be expended during June and July of 1978. If successful in solving the problem of repeatability such calculations are expected to support the hand calculations.

# 6. DIFFICULTIES WITH THE FIXES

This section attempts to deal conscientiously with any difficulties which may arise if any of the fixes is implemented. Included in it are subsections estimating core costs, timing costs and response time impact which may reasonably be anticipated if a fix is implemented.

## 6.1 Difficulties with Fix 1

### 6.1.1 Intruder aircraft

This fix has a non-zero potential error area (or volume). If an untracked aircraft is squawking a Mode 3/A code assigned to a tracked aircraft and if it is at the same radar range as that tracked aircraft ($\pm$ 1/4 nmi) and at the same altitude (assuming Mode C equipment) then its report may be suppressed by the operation of Fix 1.

The intruder aircraft must fly at the same speed as the tracked aircraft and must be within 1/4 nmi at the same distance from the radar. Otherwise it will escape the potential error area. If the intruder aircraft has operating mode C equipment it must also be at the same altitude as the tracked aircraft. The combination of circumstances is highly unlikely.

The worst feasible case for this fix is illustrated in Figures 6-1 through 6-3.

Figure 6-1 shows what happens with the present display software if an untracked aircraft is at the wrong place and time relative to a tracked aircraft. It is displayed as an uncorrelated target with a limited data block.

Figure 6-2 shows the equivalent of the algorithm 1 software in place and Mode C Intruder (MCI) logic not installed. The intruder aircraft is not displayed in this case.

Figure 6-3 shows the situation with algorithm 1 including the 4470 code (Section 2.1) implemented. MCI is not installed. The controller is in effect presented with half a loaf. The uncorrelated target reports are displayed, but the limited data block is not.

With MCI logic installed the algorithm will be overriden by the MCI and the air traffic picture shown in Figure 6-1 will be presented to the controller whether or not Fix 1 is implemented.

Fix 2 attacks the same problem as this algorithm with reasonable success. It has zero potential error area (and volume). The problem described in Figures 6-1 through 6-3 will, therefore, not arise.

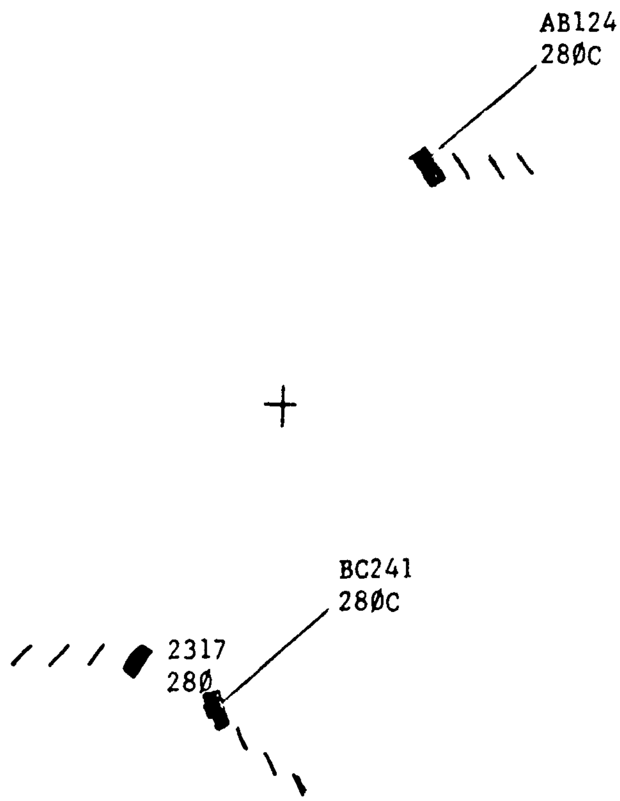



Figure 6-1 - The worst feasible case for Fix 1. Aircraft moving West identified as AB124 at altitude FL280 squawks 2317. Simultaneously an intruder aircraft is moving East at the same speed as AB124 and squawking code 2317. It is also at FL280. Both aircraft are at the same distance from the radar sensor. Without algorithm 1 the display presents the intruder aircraft approaching a near miss with flight BC241 (The symbol, +, marking the location of the radar sensor is not ordinarily displayed).

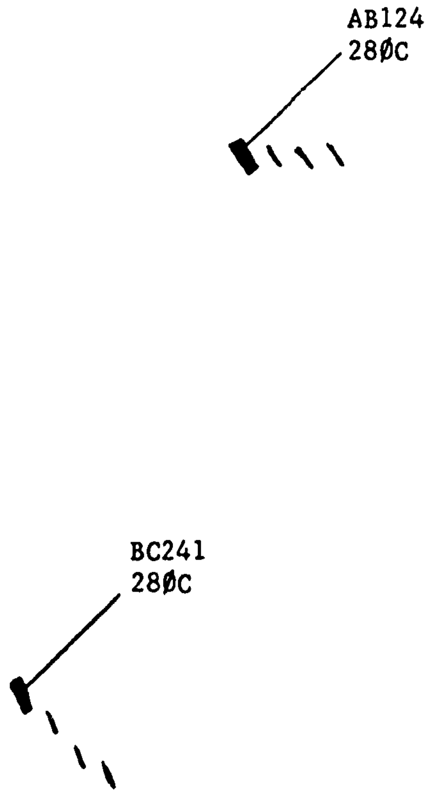



Figure 6-2 - The worst feasible case for Fix 1 (continued). Fix 1 is installed without the 4470 code and without Mode C Intruder logic. The traffic of Figure 6-1 is presented as shown here. All information concerning the intruder aircraft is suppressed.

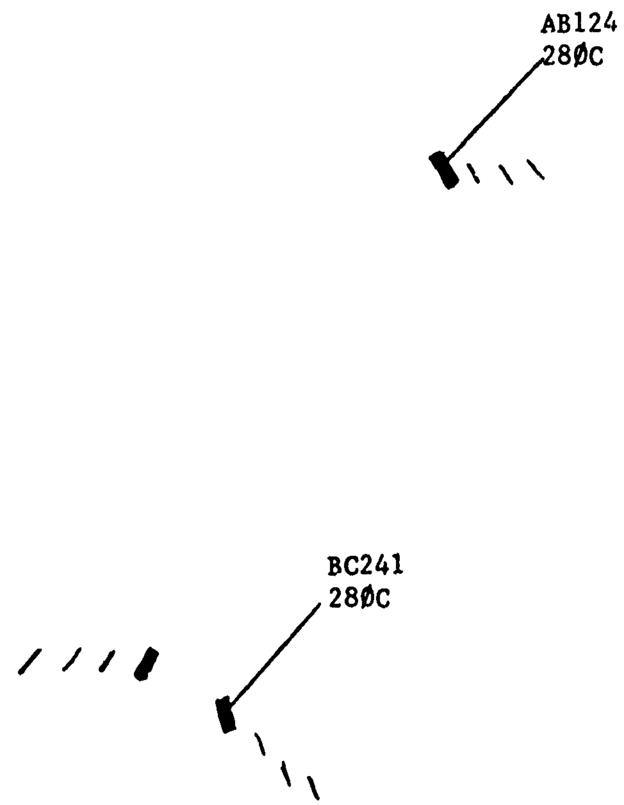



Figure 6-3 - The worst feasible case for Fix 1 (concluded). Fix 1 is supposedly implemented with the 4470 code. Mode C Intruder is not implemented. The traffic picture of Figures 6-1 takes place. The display shows the uncorrelated target symbols associated with the intruder aircraft, but not its limited data block.

### 6.1.2 Software costs of Fix 1 if implemented

Rather than proceed along the lines indicated in the flowchart of this fix (Figure 3-1), the Radar Data Table (RT) should be modified so that the spare bit is carried into it. Full processing is done only for reports with this bit set high.

Under this design core costs are estimated to be

| | | |
|---|---|---|
| Subprogram RIN: | Instructions | 3 words |
| Subprogram RTG: | Instructions | 69 words |

Timing cost for the fix is split into RIN timing and RTG timing.

Time in microseconds for the 9020A equipment is

RIN: (6 * N5)+(10 * N9)
plus RTG: (56 * N15)+(100 * N16)

For the 9020D equipment the appropriate timing estimares are

RIN: (6 * N5)+(10 * N9)
RTG: (22 * N15)+(40 * N16)

where: N5 is the number of discrete targets after selective rejection
N9 is the number of targets with spare bit set
N15 is the number of uncorrelated targets chained for display
and N16 is the number of ringaround targets.

Evaluating these formulas with the numbers of subsection 4.1.1 gives

| | |
|---|---|
| For the A Model | 0.15 milli IOCE + 0.1 milli CE |
| For the D Model | 0.3 milli IOCE + 0.08 milli CE |

This means that if the A-Model is correct then 0.00015 of the available computer time of one IOCE processor is used by the algorithm leaving 0.99985 computer time available for other chores. Similarly the CE processor is loaded by the A-Model with 0.0001 of its available computer time leaving 0.9999 available for other chores.

It does not appear feasible to measure such small quantities and the response time impact of Fix 1 is expected to be negligible.

## 6.2 Difficulties with Fix 2

### 6.2.1 Double Coverage Requirement

In order to be effective Fix 2 requires double coverage of the sensor area. This means that a second sensor must be within a reasonable distance of the problem sensor. Recalling the data of subsections 5.2.3, 5.2.3.1, 5.2.3.2, and 5.2.3.3 where it was established that Fix 2 will be effective for the QAS sensor, it appears reasonable to conclude that the algorithm will be effective if a second sensor is within 150 nmi of the first. Data on this requirement are given in Table 6.1.

It is unreasonable to suppose that 150 nmi is truly the cutoff distance for effectiveness of Fix 2. Recall that line of site coverage for the Air Traffic Control Radar Beacon System is required to be 200 nmi (Subparagraph 1.3.2 of DOT/FAA Order 1010.5A, US National Standard for the Mark X Air Traffic Control Radar Beacon System Characteristics (March 8, 1971)). Inspection of Table 6.1 shows that only the ten sensors which are asterisked have nearest neighbors more distant than 200 nmi.

The split altitude for Fix 2 should be such that the nearest neighbor radar can reliably detect aircraft beacon responses. It may be readily demonstrated that a sensor of height h above terrain can view an object a distance s if the height of that object is greater than

$$s\left(\frac{s}{2a} - \sqrt{\frac{h}{2a}}\right) \qquad (6\text{-}1)$$

where a is the earth's electromagnetic radius. The parameter a in expression 6-1 is frequently taken 4/3 of the earth's physical radius. Assume h = 100 feet, expression 6-1 is evaluated as follows

| distance | minimum altitude |
|---|---|
| 150 nmi | 13,660 feet |
| 160 | 15,640 |
| 170 | 17,750 |
| 180 | 19,950 |
| 190 | 21,920 |
| 200 | 24,850 |
| 210 | 27,500 |
| 220 | 30,210 |

Note that the minimum altitude is given here in feet and that aircraft altitudes have been described elsewhere in this report in terms of FL. In standard conditions the conversion factor is 1 FL = 100 feet.

However, conditions are rarely standard and care must be taken. In deciding on an FL value of split altitude for any RSB, allowance should be made for low barometric pressure near the RSB.

If local barometric pressure can fall below 27.91 inches Hg then it appears that the minimum altitude in FL should be as follows (NAS Configuration Management Document, Model A3d2 En Route Stage A Computer Program Functional Specifications, Multiple Radar Data Processing, NAS-MD-320 (August 15, 1974)):

Table 6-1

Nearest Neighbors greater than 150 nmi

Controller Chart Supplement Section 9, Air Route and Airport Surveillance Radar Facilities (October 11, 1977) lists 128 en route radar facilities serving 20 ARTCCs. Using 150 nmi distance to nearest neighbor in order for algorithm 2 to be effective, 14 ARTCC do not have completely adequate coverage. These ARTCCs have a total of thirty-one sensors with a nearest neighbor which is more distant than 150 nmi distant. The thirty-one are:

| Center | Sensor | Nearest Neighbor Distance |
|---|---|---|
| Albuquerque | Odessa, TX | 166 nmi |
| Atlanta | Nashville, TN | 194 |
| | Valdosta, GA | 168 |
| Boston | *Bucks Harbor, ME | 205 |
| Denver | *Gallup, NM | 248 |
| | Grand Junction, CO | 188 |
| | North Platte, NE | 195 |
| Forth Worth | Amarillo, TX | 166 |
| | Forth Worth, TX | 165 |
| | Odessa, TX | 166 |
| | Texarkana, AR | 165 |
| Houston | Alexandria, LA | 170 |
| | Houston, TX | 170 |
| Indianapolis | Lynch, KY | 178 |
| Jacksonville | Raleigh, NC | 168 |
| Kansas City | Oklahoma City | 153 |
| Memphis | Nashville, TN | 167 |
| Minneapolis | *Empire, MI | 309 |
| | Finley, ND | 171 |
| | Gettysburg, SD | 171 |
| | *Omaha, NE | 234 |
| | *Watford City, ND | 223 |
| | *Minneapolis, MN | 234 |
| Oakland | Paso Robles, CA | 162 |
| Salt Lake City | *Boise, ID | 201 |
| | *Cedar City, UT | 212 |
| | Great Falls, MT | 176 |
| | *Watford City, ND | 242 |
| Seattle | Salem, OR | 170 |
| | Seattle, WA | 170 |
| | *Spokane, WA | 207 |

*Indicates nearest neighbor more than 200 nmi distant.

| distance | minimum altitude |
|---|---|
| 150 nmi | FL 162 |
| 160 | 181 |
| 170 | 205 |
| 180 | 225 |
| 190 | 247 |
| 200 | 274 |
| 210 | 300 |
| 220 | 327 |

### 6.2.2 Software Costs of Fix 2 if implemented

Rather than proceeding as described in the flow chart of Figure 3-3, the Fix 2 algorithm should do nothing until after radar sort box (RSB) assignment. If a target report is in one of the split altitude RSB's then full processing must take place.

With Fix 2 implemented, each RSB in an Air Route Traffic Control Center must be further described in the computer with two additional bytes. For the maximum size system an additional core of 2048 words in each IOCE is required.

Further the instructions count for the algorithm is estimated to be 80 words. Total additional core is estimated at 2128 words for an ARTCC which is geographically large.

The timing estimate for this algorithm is one compare, costing 6 usec, for each target which passes selective rejection and is not in a split altitude RSB. For target reports requiring full processing the estimate is 160 usec for each of them.

As a formula this is: (6 * N5)+(160 * N10)

where N5 is the number of discrete target reports which pass selective rejection
and N10 is the number of such targets in the split altitude RSB's.

Evaluating the formula with the models of subsection 4.1.4 gives

| | |
|---|---|
| For the A Model | 0.86 milli-IOCE |
| For the D Model | 1.99 milli-IOCE |

The effect on response time of this loading cannot be estimated.

### 6.3 Difficulties with Fix 3

#### 6.3.1 Intruder aircraft

This fix has essentially the same difficulty as Fix 1. Figure 6.4 shows an aircraft identified as DE125 in such a position that reflection geometry identifies the intruder squawking 2318 as a false target.

As with Fix 1 the options available are: (1) suppress the intruder symbol and its appropriate limited data block, or (2) suppress the limited data block only. Also, as with Fix 1, MCI logic will be expected to override the suppression logic.

#### 6.3.2 Software Costs

##### 6.3.2.1 Software Costs of Fix 3A if implemented

Estimates for a reasonable core burden for the "A" version of Fix 3 as an algorithm coded into the Beacon Primary Radar Message Processing Subprogram (RTG) is:

| | |
|---|---|
| Instructions | 304 words |
| Tables | 128 |
| Sum | 432 words |

Estimated timing cost for this version, in microseconds for the 9020A system is

$$(35 * N5)+(40 * N12)$$

and for the 9020D system it is

$$(14 * N5)+(16 * N12)$$

where N5 is the number of target reports passing selective rejection and N12 is the number of false targets on or near the problem bearing.

Evaluating these formulas with the models of subsection 4.1.4 gives

| | |
|---|---|
| For the A Model | 0.66 milli CE |
| For the D Model | 0.68 milli CE |

Response time of the system may be adversely affected.

##### 6.3.2.2 Software Costs of Fix 3B if implemented

This version of Fix 3 will consist of a modification to the Radar Input Subprogram (RIN) which resides in the IOCE. No significant improvements on the program patch which was prepared are foreseen.

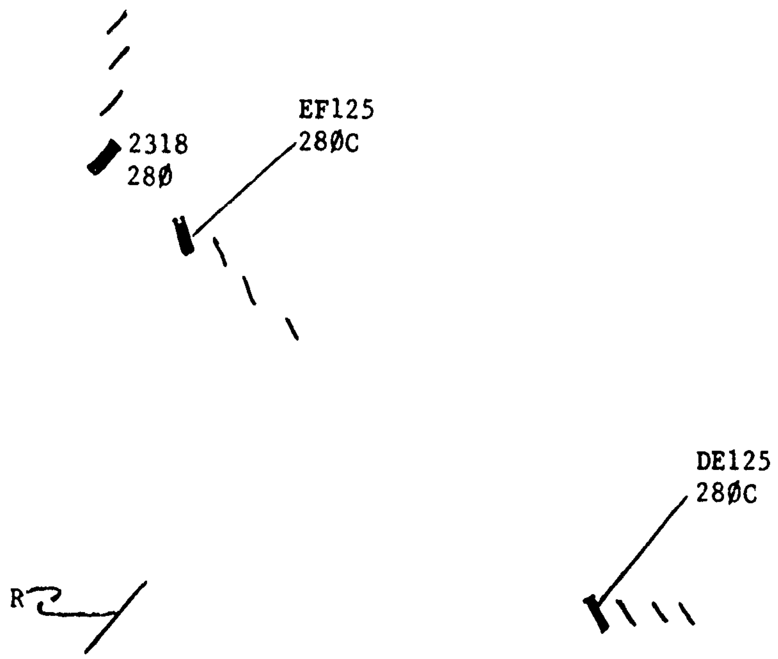



Figure 6-4 - The worst feasible case for Fix 3. Aircraft identified as DE125 is squawking 2318 flying west at 28,000 feet as shown on the plan view display. Its reflections from reflector R are in the same area as those of an intruder aircraft also squawking 2318 and also at an altitude of 28,000 feet. Without Fix 3 the display presents the intruder aircraft approaching a near miss with flight EF125. With Fix 3 implemented, the reports associated with the intruder aircraft may be lost.

The estimate of additional core requirement is

| | |
|---|---|
| Instructions | 180 words |
| Data and Tables | 702 |
| Sum | 882 words |

The timing estimate is

(57 * N11)+(241 * N18)

where N11 is the number of target reports in the problem area
and N18 is the number of targets on or near the problem bearing.

Evaluating with the model of subsection 4.1.4 gives

| | |
|---|---|
| For the A Model | 0.06 milli IOCE |
| For the D Model | 0.15 milli IOCE |

This version of Fix 3 impacts only IOCE timing and will have a small but beneficial effect on CE timing. Overall impact on response time is unknown.

### 6.3.3 Additional hardware required for Fix 3B

If the "B" version of Fix 3 is implemented then three additional adapters will be required for each problem CD site. Cost for each site is $12,000 plus installation.

### 6.3.4 Fix 3A or Fix 3B or Neither

If a site has a problem with reflected reports and the reflectors can be identified, it may then be necessary to decide on the relative merits of Fix 3A or 3B.

If most of the reflected targets are tracked then Fix 3A, which requires no additional hardware, is the choice as it has core loading roughly half of that of Fix 3B.

However, if the reflected targets are not tracked in NAS Stage A then Fix 3B would have to be considered. This fix essentially prepares its own file of all mode 3/A discrete beacon targets.

The competitor for these fixes is the so-called "Trevose" fix which suppresses replies by adjusting the directivity of the "omnidirectional" antenna.

### 6.4 Difficulties with Fix 4

#### 6.4.1 Intruder aircraft

This algorithm has a very large potential error area. Described another way, if two aircraft are squawking the same beacon code then one of them must be more distant from the sensor than the other. If the more distant aircraft is not tracked and Fix 4 is operating, the aircraft will not ordinarily be displayed to the controller as an uncorrelated data block. It is easy to construct various rules the object of which is to prevent this sort of blunder. It is not easy to ensure that these same rules will in fact prevent the blunder.

Fix 4 if implemented would almost certainly require either the 4470 code or Mode C intruder logic.

Fix 4 requires that an IOCE "know" all targets being processed by the CD which is experiencing reflections. This will require three additional adapters for each problem CD. The cost of these three adapters is $12,000 for each problem CD.

#### 6.4.2 Software Costs of Fix 4 if implemented

The algorithm for this fix must be coded into the IOCE. A large site table is required. Best estimate of table size and instruction count is:

| | |
|---|---|
| Table | 2006 words |
| Instructions | 282 |
| Sum | 2288 words |

It is estimated that each target report will require 66 usec of processing. As a formula the timing estimate is

N2 * N3 * 66

where N2 is the number of sensors
and N3 is the number of target reports from the Common Digitizers

Evaluating with the model of subsection 4.1.4 gives

| | |
|---|---|
| For the A Model | 26.5 milli IOCE |
| For the D Model | 66.8 milli IOCE |

The response time impact is expected to be adverse but quantitative estimates are not available.

### 6.4.3 Additional hardware required for Fix 4

If implemented this fix will require three additional CD adapters for each problem sensor. Cost of these three adapters is $12,000 plus installation.

## 6.5 Difficulties with Fix 5

### 6.5.1 Missed good reports

As documented in JWT and reported in subsection 5.5 of this report, some good target reports may be missed if this fix is adapted.

### 6.5.2 Software Costs of Fix 5 if implemented

For purposes of estimating core costs the following figures are relevant. They are from contractor coding

| | |
|---|---|
| Instructions | 52 words |
| Data and Tables | 56 |
| Sum | 108 words |

The timing estimate for this fix for the 9020A and the 9020D system is

| 9020A system | 9020D system |
|---|---|
| 27.4 * N15 | 11 * N15 |

where N15 is the number of targets chained for display

Evaluating these expressions with the model of subsection 4.1.4 gives

| | |
|---|---|
| For the A Model | 0.36 milli CE |
| For the D Model | 0.32 milli CE |

## 6.6 Difficulties with Fix 6

There are three difficulties described in subsections 6.6.1 through 6.6.3 following. The software costs, described in subsection 6.6.4 are included in section 6 for consistency. In fact they may be negative: i.e. some additional processing time may become available if Fix 6 is implemented.

### 6.6.1 Hardware modification to the Common Digitizer is required

In the current test design determination of a split is made in the IOCE. In order for Fix 6 to function with this design, the CD which is experiencing split targets must be dedicated to a single IOCE.

This situation is in contrast to the present operational design where target reports from a single CD are ordinarily shared among the available IOCE's. Usually there are two IOCE's on line. If the algorithm is implemented in IOCE software then each CD would require three additional adapters. The estimated cost for these three adapters is $12,000. Nationally, allowing for 100 sites, total adapter cost would exceed $1,000,000 in hardware.

These additional adapters are required to preserve the fail safe characteristics of the subsystem consisting of IOCE's, Peripheral Adapter Modules, and the CD.

From a cost/benefit viewpoint a more economical approach is to modify the CD, performing the split determination at the CD and suppressing or (preferably) setting a flag on a split target before transmission to the ARTCC.

Cost for this modification, if adopted, is estimated to be $30,000 for an experimental kit and $150,000 for 100 production kits. Each production kit will consist of a one card modification, two spare cards and installation instructions. Installation is not included in this estimate. Extra kits are estimated to cost $750 each.

Build and test of the experimental kit is estimated at nine months from data of contract. Production would probably be at the rate of twenty per month. Thus initial deployment is, optimistically, one year from award date.

### 6.6.2 Intruder Aircraft

If there is a blunder to the effect that an aircraft is squawking the identical Mode 3/A code as that of a tracked aircraft and the two aircraft squawking this code approach too close to one another then the untracked aircraft will be suppressed from this display. In the version of the algorithm coded for test the meaning of "too close" is 1/8 nmi in range and 1½ nmi in bearing. By 1½ nmi in bearing is meant that the product of range and bearing difference where bearing difference is measured radian must be less than 1½ nmi for the algorithm to operate.

Under these circumstances the situation which is illustrated in Figures 6-5 through 6-7 could be critical.

It is probably not reasonable to make a real estimate of the compound probability of blunders required to lead to the situation of Figures 6-5 through 6-7. Such an estimate would include (1) the wrong code (one in 4032) at (2) the wrong place and time (no data available on blunders into controlled airspace).

The responsibility for balancing the above described hazard with the benefits of eliminating 80% to 100% of the split target reports rests with the operating services.

### 6.6.3 Delay in Target Reports from Common Digitizer

Fix 6 requires a holding table. For test purposes the most recent five discrete beacon targets are held in the table and not released until a sixth target is received from the CD. See subsection 3.6.1.1.

A spot check of 27 instances from the IND tape shows that increased time delays of targets from the CD can be expected to vary between 0.1 sec and 1.1 sec with a five target hold table.

However, a two or three target hold table will give the same results as the target splits rarely are more than one target apart. That is the split is not expected to appear consecutively as: 3217, XXXX, XXXX, 3217. A sample of twenty-seven instances suggests that with a two or a three target hold table, target delay varies up to 0.5 sec.

It is, of course, possible to build a timeout feature into the algorithm so that any target delayed more than, say, one second, is released without waiting for additional targets to "age" it.

### 6.6.4 Software costs of Fix 6 if implemented

Without the 4470 code, that is if the fix is adapted to discard bad target reports, the software cost is negative. No additional code is required and the processing for some target reports is eliminated. This will buy back small quantities of IOCE time and CE time.

If Fix 6 is implemented in the manner that the limited data block associated with the purportedly false report is not to be displayed but the position report is to be displayed, then a code similar to that developed by R. Copes, AAT-540 and R. Delaney ANA-140 will have to be added to the operational software. As coded this costs

8 words in subprogram RIN
1 word in the Idle-Time Radar Data Processor Subprogram (RSL)
3 words in subprogram RTG

The timing costs associated with this code are estimated to be, for the 9020A

(1) in the IOCE (6 * N5) + (42 * N17)
(2) in the CE 24 * N17

Those associated with this 9020D are

(1) in the IOCE: (6 * N5) + (42 * N17)
(2) in the CE 10 * N17

where N5 is the number of target reports after selective rejection and N17 is the number of split reports.

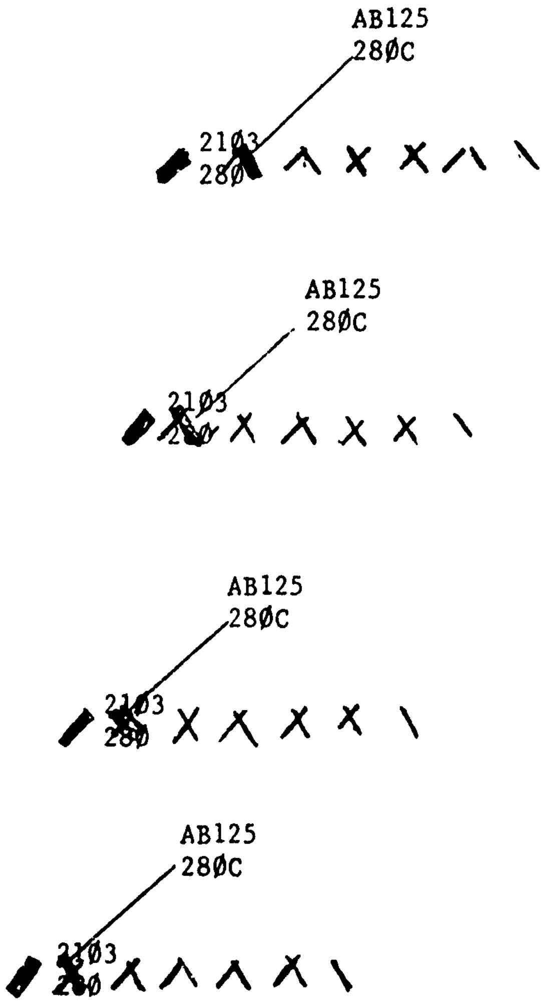



Figure 6.5 - The worst feasible case for Fix 6. An aircraft identified as AB125 is flying west at FL280 making good 450 knots. It is overtaking a second aircraft at the same altitude which is squawking the same mode 3/A code (2103) and making good 400 knots. The sensor is supposed to be due South of the two aircraft. This figure shows four consecutive updates of the picture presented on the PVD without Fix 6 installed. The same picture is presented with the fix installed with the Mode C intruder logic operating.

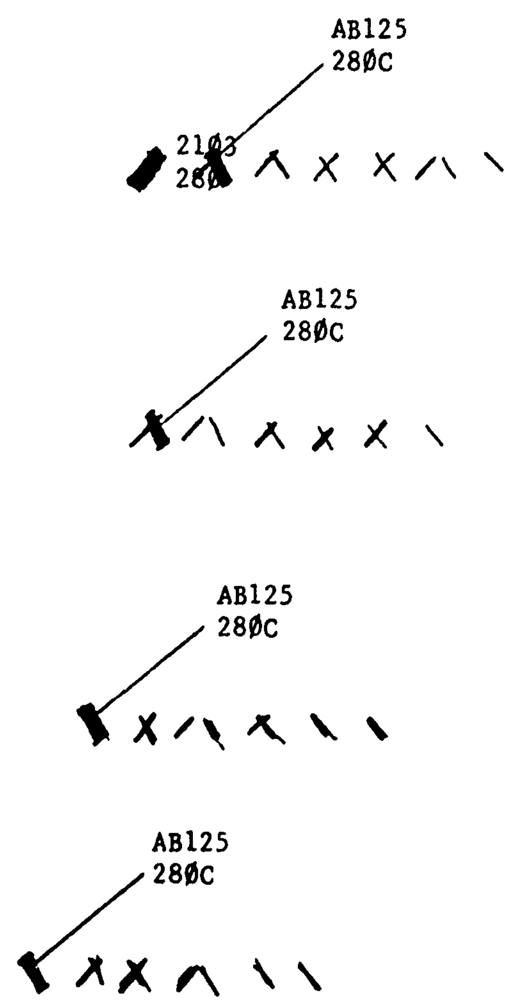



Figure 6-6 - The worst feasible case for Fix 6 (continued). The situation described in Figure 6-5 occurs and Fix 6 without the 4470 code is assumed implemented. The overtaken aircraft, an intruder, is displayed only on the first of the updates shown here. Its symbol and limited data block are suppressed in the last three updates and it appears there only as a history display.

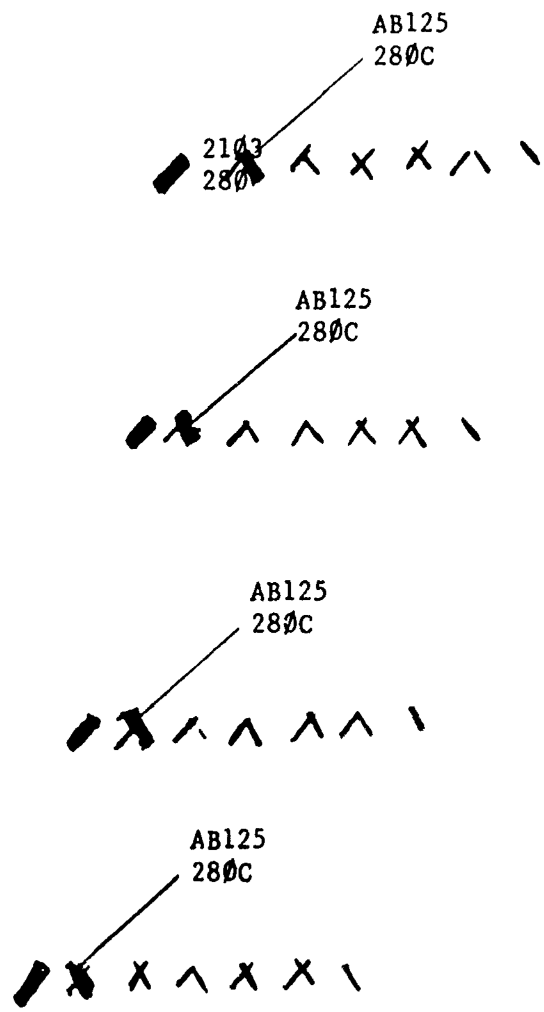



Figure 6-7 - The worst feasible case for Fix 6 (continued). The situation described in Figure 6-5 occurs and Fix 6 is assumed implemented with the 4470 code. The symbol for the overtaken aircraft is displayed for all updates, but its limited data block is only displayed on the first of the updates shown here.

Evaluating the above expressions with the models of subsection 4.1.4 gives

| | |
|---|---|
| For the A Model | 0.15 milli IOCE + .005 milli CE |
| For the D Model | 0.3 milli IOCE + .004 milli CE |

This estimate is in fact an upper limit on timing impact. False targets require processing time and this factor has not been included in the analysis of this subsection.

## 7. SUMMARY

Six candidate fixes to attack the problem of false discrete target reports have been studied.

During the course of the study data was gathered from three en route sites during calendar year 1976. The data became the data base for evaluating the effectiveness of each of the fixes.

Evaluation was based both on a careful study of relatively few instances of false targets and on a study of a larger number of instances using the 9020 partly as a collating and calculating machine.

Results with the 9020 calculation are suspect in many cases and complete repeatability from run to run was not always obtained.

It appears that the ringaround type of false target can be eliminated in several ways. Since the en route airspace has double radar coverage the simplest way of doing it is to reassign the preferred radar sensor for the area where ringaround occurs. A scheme whereby the reassignment is made on the basis of the radar sort box grid system was investigated and seems to hold promise.

One method of eliminating the split type of false target was investigated. This method eliminates 40% or more of this type of target. Efficiency can approach 100% if one of its parameters, azimuth distance between targets, is relaxed from 1-½ nmi to 5-½ nmi.

The reflection type of false target can be eliminated only with difficulty. In the special case that a reflector can be identified, reflected target reports may be eliminated if the target causing the report is a tracked target.

## 8. RECOMMENDATIONS

It is recommended that: (1) Fix 2 in the form of algorithm 2 be implemented at sites where ringaround is a problem, (2) Consideration be given to implementing Fix 6 as a hardware modification to the Common Digitizer at sites where split targets are a problem, and (3) Consideration be given to implementing Fix 3A as a software algorithm at sites where (a) reflected target reports are a problem, (b) a reflector can be identified and cannot be physically removed and (c) the reflected reports are generally due to targets which are within the Air Route Traffic Control Center where the reflected reports occur.

### 8.1 Implement Fix 2 against ringaround

The bases for this recommendation are shown in section 5.2 and the subsections thereto and in section 6.2 and the subsections thereto of this report. The data and arguments of section 5 deal with the benefits of the fixes and the data and arguments of section 6 with their overall costs.

In Fix 2 was found the only instance in which hand analysis and machine analysis support each other. The results suggest that the fix will be successful in eliminating many ringaround target reports.

The code which was used in the machine analysis is not suitable for implementation. It will have to be rewritten for such implementation.

A split altitude at FL235 is suggested for purposes of uniformity. If adopted this will eliminate about 75% of the false reports classified, in this report, as ringaround.

If FL235 is chosen as the split altitude then ringaround problems at the high altitude sectors will be ameliorated. Those associated with low altitude sectors will remain. If dissatisfaction with ringaround in low altitude sectors should be reported then it may be possible to lower the split altitude to take care of some of the ringaround problem. It will in any case be necessary to confirm that the near neighbor radar can adequately cover the airspace near the problem radar.

If double radar coverage for a site can be shown then the main drawback to Fix 2 is a storage cost of between 1,200 and 2,000 words in each of the IOCE processors.

It is estimated that a version of Fix 2 suitable for national implementation can be designed, coded and tested within three months of go ahead time. Contractor cost for this effort is estimated at $12,000.

## 8.2 Consider implementation of Fix 6 against splits

This recommendation is weaker than that of subsection 8.1 above. The sole reason for this weakness is that fact that the algorithm could not be successfully run for machine analysis. As mentioned in subsection 5.6.4 effort is being expended to remedy this situation.

It is suggested that (1) the 4470 code be included so that the target reports of split targets, but not their limited data blocks are displayed and (2) the distance restriction of 1-½ nmi be removed so that the effectiveness of the fix may approach 100%. So adopted, Fix 6 should eliminate essentially all of the limited data blocks associated with the split type of false target report.

Since this type of false report is by far the most prevalent, this fix is most effective from the point of view of number of reports affected.

There are three drawbacks to Fix 6: (1) A hardware cost, as estimated in subsection 6.6.1, of $180,000, (2) a software cost corresponding to the 4470 code (subsection 6.6.4) and (3) the potential of the situation shown in Figures 6-5 through 6-7.

It is estimated that the hardware for Fix 6 could be delivered to the field beginning about one year from award of a contract for a prototype kit. This estimate assumes a six month build cycle for the prototype kit, a three month evaluation and a three month startup for production of initial field kits. Production is estimated at twenty kits per month.

The 4470 code, suggested to be used in conjunction with Fix 6, is already developed and is in the process of being tested.

## 8.3 Consider implementation of Fix 3 against reflection

This fix is in the form of a software algorithm with or without additional hardware. Fix 3A requires no additional hardware. Fix 3B requires hardware adapters costing $12,000 for each problem site. Fix 3 worked successfully as a fix in hand analysis of ZJX and ZNY and in a purely simulated environment.

This fix is useful only in the special case where targets are reflected from known reflectors. In this situation, it is suggested that Fix 3 be considered as a potential eliminator of reflected target reports (subsection 5.3). Consideration must include (1) false reports from a specific site, (2) a study of the reflection phenomena at the site to determine if a problem bearing and a reflector can be found and (3) the competition of the "Trevose" fix to solve the same problem (subsection 6.3.4).

It is estimated that an algorithm based on Fix 3 suitable for implementation can be designed, coded, and tested within six months of go ahead time. Contractor cost is estimated at $22,000.

## APPENDIX A

## IDENTIFYING RINGAROUND TARGET REPORTS

### A.1 General

Initial inspection of the data base for ringaround consists of examining a Beacon False Target Analysis (BFTA) list made from the appropriate tape. BFTA default parameters used were AZ1 = 45°, max range = 200 nmi (Computer Program Functional Specification, Beacon False Target Analysis Program, FAA-4106P-1 (11 June 1976)).

The Ringaround BFTA list is usually quite small. For IND it has only 39 entries.

A COMDIG listing of the CD Record tape is made up using mode 3/A codes selected from inspection of the BFTA Ringaround listing and appropriate start-stop times. For example, the IND BFTA Ringaround listing of 39 entries had 11 candidate codes.

COMDIG lists range and bearing for a maximum of five codes ordered chronologically. Inspection of these lists for ringaround targets is non-trivial for target range less than 15 nmi.

Determination of the true targets embedded in a set of false targets in a COMDIG listing is frequently made analytically. The target velocity is determined from measurements of range and bearing far from the sensor. One observation before ringaround and one after suffices to give west to east velocity, $\dot{x}$, and south to north velocity, $\dot{y}$.

From the geometry of the situation the change in target bearing over a period of time, $\Delta t$ is

$$\Delta\theta = \Delta t \ \frac{2048}{\pi} \ \frac{(\dot{x}\cos\theta - \dot{y}\sin\theta)}{r^2 - Z^2} \qquad (A-1)$$

where r is slant range, Z is altitude, $\theta$ is bearing, and $\Delta\theta$ change in bearing. Bearing is measured in ACP (2048 ACP = 180° = $\pi$ radians).

A programmable calculator, Texas Instrument Model SR-52, is programmed to calculate $\Delta\theta$ given $\Delta t$, r, Z, $\theta$, $\dot{x}$, and $\dot{y}$. On a scan by scan basis it is usually possible to find the target with the correct range and bearing from this analysis. By "correct" here is meant the range and bearing along which the "true" target travels in a straight line. Occasionally this analysis breaks down very near the sensor. Resort is them made to hand plots of the data.

Note that this determination of ringaround labels as "ringaround" many targets which ordinarily are not considered ringaround targets. In effect all targets associated with an aircraft which BFTA determines to "ring" are included.

There results some instances where a ringaround report will not be affected by any reasonably sized computer algorithm. For example in the ringaround data base it was found that the aircraft squawking 2527 gives false reports out to a range of 114 nmi. In the analysis it was felt better to classify all false reports associated with code 2527 as ringaround reports rather than to impose an arbitrary range cutoff and classify the longer range false reports as reflection type reports.

## A.2 Example of Ringaround

Table A.1 contains an example of COMDIG data from which a determination of ringaround is made. An aircraft is squawking 7257 on mode 3/A and the equivalent of FL368 on Mode C. The observations are from the IND radar. To determine time add 2100Z to the entries in the first column.

First altitude above the ground plane, Z, is estimated to be 35,955 feet. This is pressure altitude (36,800 feet) less the assumed height of the IND radar (845 feet). Pressure correction is not made. From this altitude projected coordinates are determined at times 21 hr 40 min 53.6 sec and 21 hr 44 min 50.1 sec. Dividing the coordinate differences at these times by the difference in time (3 min 56.9 sec) gives the components of velocity: $\dot{x}$ = 0.136 438 nmi/sec and $\dot{y}$ = 0.007 470 19 nmi/sec. Noting that the time of a radar scan is 10.1 sec at IND the following quantities on the right hand side of equation A-1 are known: Z(35,955 feet = 5.41 nmi), $\Delta t$(10.1 sec), $\dot{x}$ (0.136 nmi/sec) and $\dot{y}$ (0.007 nmi/sec ).

These quantities are entered into the calculator. Next the quantities corresponding to radar range and bearing from the COMDIG listing are entered. The calculation of $\Delta\theta$ is performed according to equation A-1 and a search of the listing is made to identify a target with its bearing changed by $\Delta\theta$. Such a target is marked G. Those target reports which do not conform to the equation are declared false and marked X.

Table A-1 gives data from the COMDIG printout for all targets squawking 7257 between 21 hr 40 min 23.1 sec and 21 hr 43 min 50.1 sec. The declaration G or X is added as a result of calculation.

It is not shown directly in Table A-1, but there are six target reports missing. There should be targets squawking 7257 at the following times (2100Z omitted): (1) 40 min 33.2 sec, (2) 41 min 34.3 sec, (3) 41 min 44.4 sec, (4) 43 min 39 sec, (5) 44 min 9.6 sec, (6) 44 min 29.8 sec, and 44 min 39.9 sec.

Table A-1

Example of COMDIG printout. Time, radar range, bearing and time since last report are supplied by COMDIG. The designation G (meaning good target) or X (meaning ringaround target) next to the bearing listing is determined as described in the text.

| Time (add 2100Z to all times) | Radar Range nmi | 1/8 | Bearing ACP | Time (since last report) |
|---|---|---|---|---|
| 40 m 23.1 s | 16 | 3 | 3272G | 10.2 |
| 43.2 s | 14 | 0 | 3282X | 20.2 |
| 43.4 s | 13 | 7 | 3318G | 00.1 |
| 53.6 s | 12 | 6 | 3335G | 10.2 |
| 41 m 03.6 s | 11 | 6 | 3334G | 10.0 |
| 09.5 s | 11 | 1 | 1612X | 05.9 |
| 14.0 s | 10 | 5 | 3409G | 04.5 |
| 18.1 s | 10 | 2 | 1011X | 04.1 |
| 24.2 s | 9 | 6 | 3461G | 06.1 |
| 38.7 s | 8 | 4 | 1137X | 14.5 |
| 40.4 s | 8 | 3 | 1861X | 01.7 |
| 41.0 s | 8 | 3 | 2095X | 00.6 |
| 49.7 s | 8 | 0 | 1458X | 08.7 |
| 50.3 s | 7 | 7 | 1742X | 00.6 |
| 51.1 s | 7 | 7 | 2126X | 00.8 |
| 55.4 s | 7 | 6 | 3828G | 04.3 |
| 42 m 00.3 s | 7 | 5 | 1616X | 04.9 |
| 00.7 s | 7 | 5 | 1743X | 00.1 |
| 01.4 s | 7 | 5 | 1881X | 00.3 |
| 06.0 s | 7 | 5 | 2110X | 00.7 |
| 11.1 s | 7 | 5 | 4031G | 04.6 |
| 11.6 s | 7 | 5 | 1940X | 05.1 |
| 11.8 s | 7 | 5 | 2162X | 00.5 |
| 16.6 s | 7 | 6 | 2343X | 00.2 |
| 20.8 s | 7 | 7 | 0150G | 04.8 |
| 21.0 s | 7 | 7 | 1823X | 04.2 |
| 21.5 s | 7 | 7 | 2073X | 00.5 |
| 22.5 s | 7 | 7 | 2509X | 01.0 |
| 22.6 s | 7 | 7 | 2559X | 00.1 |
| 27.3 s | 8 | 1 | 0327G | 04.7 |

| Time (add 2100Z to all times) | Radar Range nmi | 1/8 | Bearing ACP | Time (since last report) |
|---|---|---|---|---|
| 42 m 31.9 s | 8 | 3 | 2230X | 04.6 |
| 32.3 s | 8 | 3 | 2372X | 00.4 |
| 33.3 s | 8 | 3 | 2772X | 01.0 |
| 33.7 s | 3 | 4 | 2920X | 00.4 |
| 33.7 s | 3 | 4 | 2986X | 00.0 |
| 37.6 s | 8 | 6 | 0451G | 03.9 |
| 43.7 s | 9 | 1 | 2905X | 06.1 |
| 44.0 s | 9 | 2 | 3035X | 00.3 |
| 48.0 s | 9 | 4 | 0533G | 04.0 |
| 58.3 s | 10 | 4 | 0633G | 10.3 |
| 43 m 08.4 s | 11 | 3 | 0632X | 10.1 |
| 08.5 s | 11 | 4 | 0639G | 00.1 |
| 18.7 s | 12 | 4 | 0688G | 10.2 |
| 28.9 s | 13 | 5 | 0717G | 10.2 |
| 49.2 s | 15 | 7 | 0764G | 20.3 |
| 59.4 s | 17 | 1 | 0786G | 10.2 |
| 44 m 19.7 s | 19 | 5 | 0812G | 20.3 |
| 50.1 s | 23 | 4 | 0844G | 30.4 |

# APPENDIX B

## DART BEACON ANALYSIS

### B.1 Overview

The DART Beacon Analysis Procedure has been developed to provide statistical information on various Beacon Algorithms assigned to be tested. The procedure compares baseline SAR (SARB) recordings to Algorithms SAR (SARM) recordings, and it provides a summary as well as a detailed output listing of all targets analyzed.

### B.2 DART Beacon Analysis Processing Flow

The Beacon Analysis procedure consists of four steps:

- Baseline Preprocessing
- Analysis Processing
- Analysis
- Report Generation

Figure B-1 presents a flow of this procedure.

#### B.2.1 Baseline Preprocessing

Baseline processing creates the Baseline Master Edit tape from the Baseline System Analysis Recording (SAR) tape. The DART system edits the SAR tape and produces a tape with Beacon data only. When the baseline preprocessor is finished, a Master Edit tape has been produced with only SAR recording code 140 present.

#### B.2.2 Analysis Preprocessing

Analysis preprocessing creates the Algorithm Edit tape and disk files to be used in the analysis step. The Algorithm Edit tape consists of SAR code 140. The three disk files contain SAR recording codes 85 and false target lists.

SAR Code 140 - This is an existing SAR code which has been moved to provide more reliable data for analysis.

SAR Code 85 - This SAR code has been added to provide a means of recording information when any of the algorithms determines that it has a false target that should be eliminated from processing.

These have been preprocessed into separate groups:

- Unmatched false targets
- 85/false target matches
- Unmatched 85 records

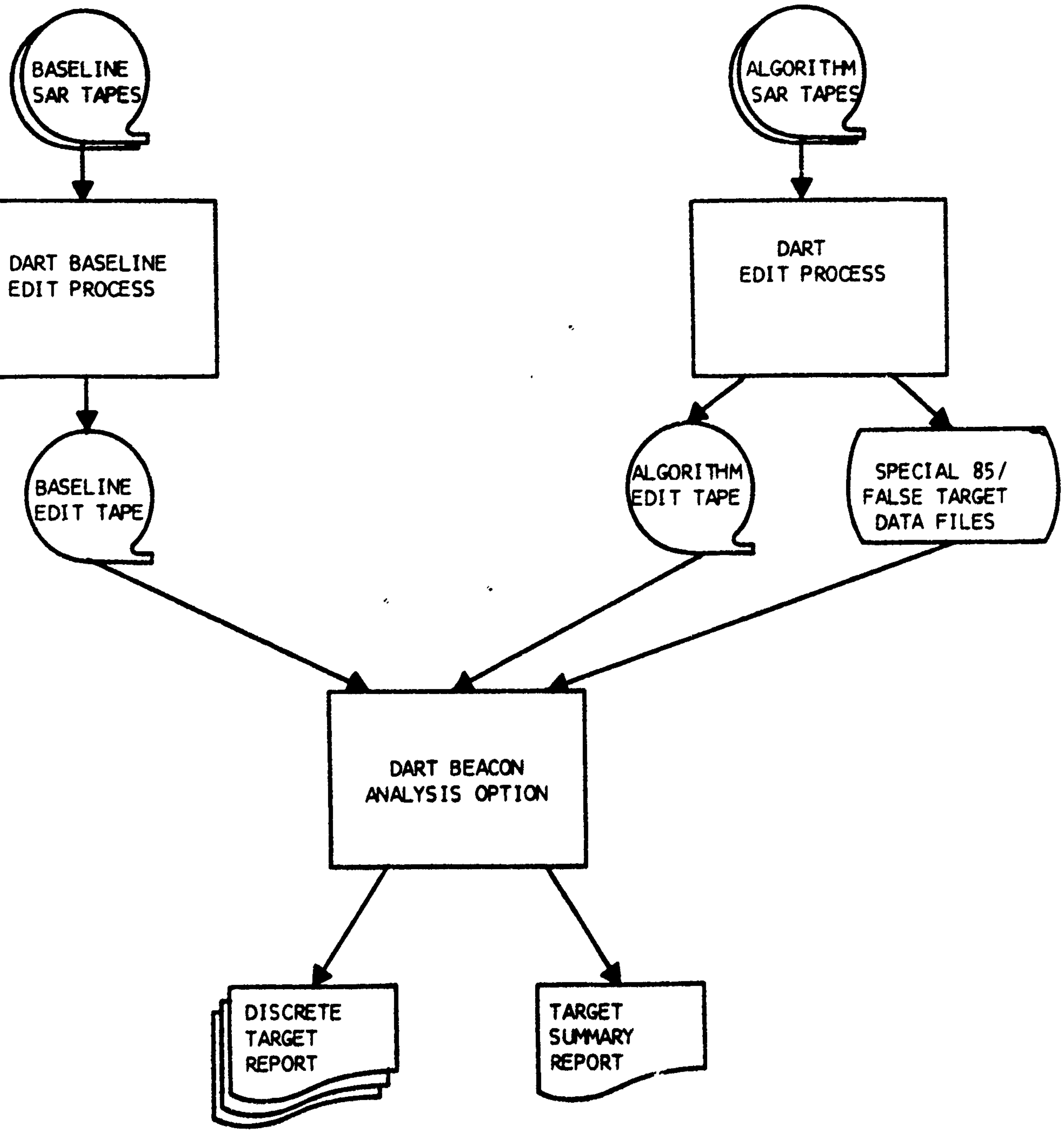



Figure B-1. Flow of Analysis Processing

### B.2.3 Analysis

Analysis compares the five unique types of data and creates a truth table entry for each target analyzed (see Table B-1). The program performs five compares in different sequences to determine into which category each target falls in the truth table. Upon completion, the analysis step has produced a file of targets analyzed, and a summary of the statistics generated.

### B.2.4 Report Generation

Report Generation sorts the target files produced in the analysis step, reformats these files for output, and outputs the resulting reports (see Figure B-2).

TABLE B-1. BEACON ANALYSIS TRUTH TABLE

| BASELINE | 140 | 85 | FALSE/TARGET | CATEGORY | CATEGORY DESCRIPTION |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | | ERROR |
| 1 | 1 | 1 | 0 | | ERROR |
| 1 | 1 | 0 | 1 | 1 | FALSE TARGET NOT SUPPRESSED |
| 1 | 1 | 0 | 0 | 2 | TRUE TARGET NOT SUPPRESSED |
| 1 | 0 | 1 | 1 | 3 | FALSE TARGET SUPPRESSED |
| 1 | 0 | 1 | 0 | 4 | TRUE TARGET SUPPRESSED |
| 1 | 0 | 0 | 1 | 5 | FALSE TARGET LOST |
| 1 | 0 | 0 | 0 | 6 | TRUE TARGET LOST |
| 0 | 1 | 1 | 1 | | ERROR |
| 0 | 1 | 1 | 0 | | ERROR |
| 0 | 1 | 0 | 1 | 7 | FALSE TARGET NOT SUPPRESSED ADDED |
| 0 | 1 | 0 | 0 | 8 | TRUE TARGET ADDED |
| 0 | 0 | 1 | 1 | 9 | FALSE TARGET SUPPRESSED ADDED |
| 0 | 0 | 1 | 0 | 10 | FALSE TARGET ADDED |
| 0 | 0 | 0 | 1 | 11 | BAD FALSE TARGET CARD ENTRY |
| 0 | 0 | 0 | 0 | | ERROR |

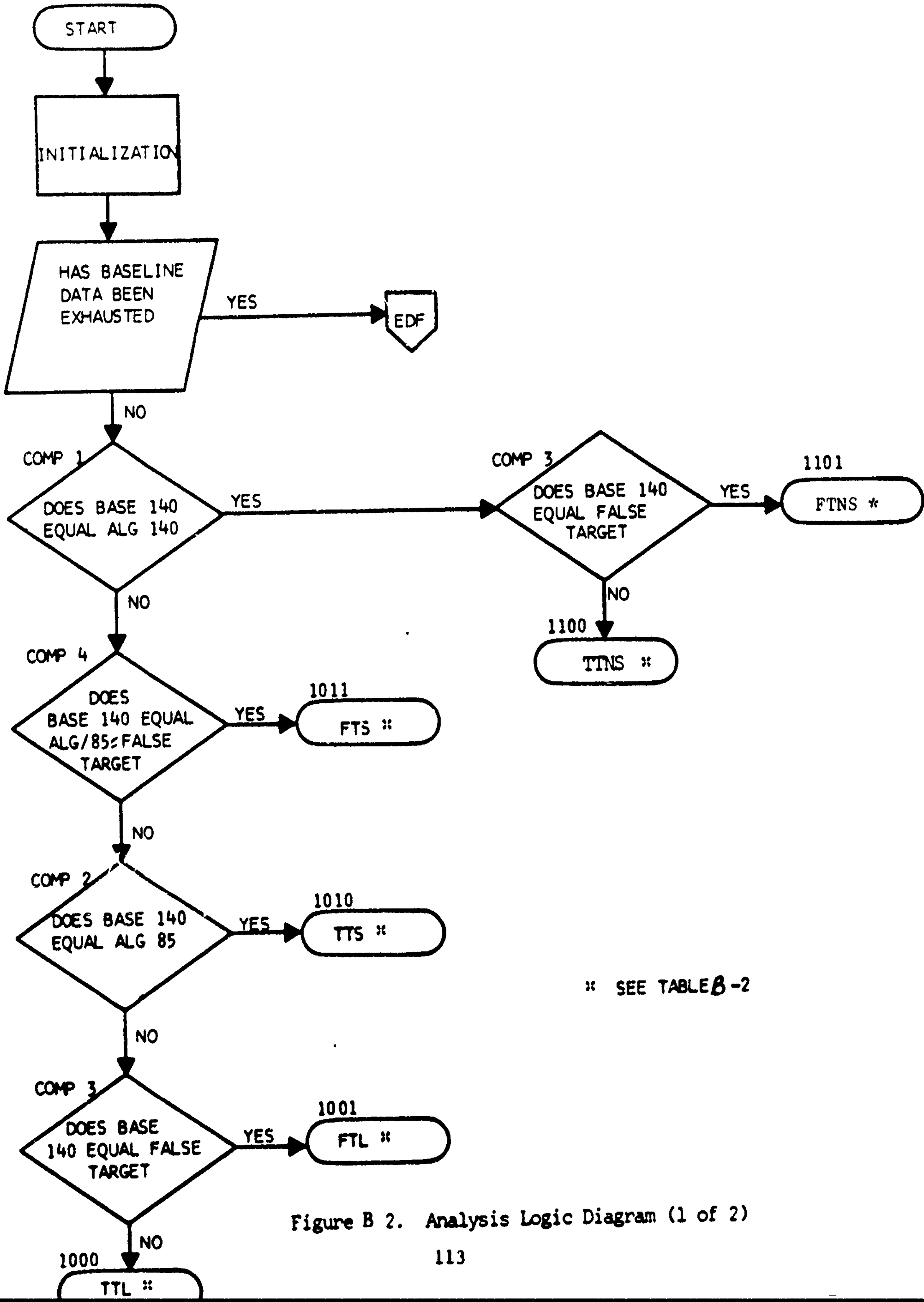



Figure B 2. Analysis Logic Diagram (1 of 2)

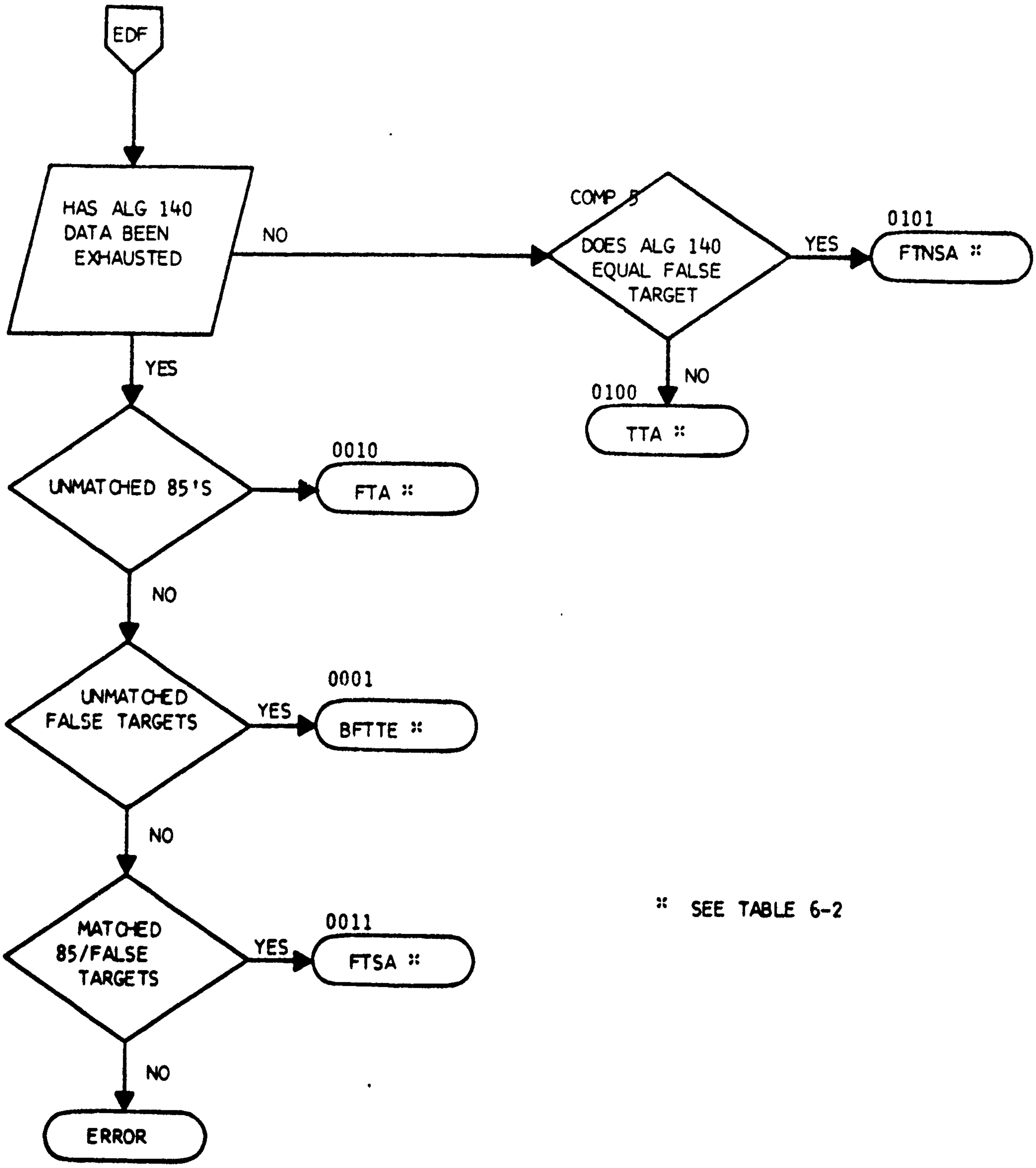



Figure B-2. Analysis Logic Diagram (2 of 2)

Table B-2. False Target Nonmenclature

| | | | |
|---|---|---|---|
| FTNS | - | FALSE TARGET NOT SUPPRESSED | 1101 |
| TTNS | - | TRUE TARGET NOT SUPPRESSED | 1100 |
| FTS | - | FALSE TARGET SUPPRESSED | 1011 |
| TTS | - | TRUE TARGET SUPPRESSED | 1010 |
| FTL | - | FALSE TARGET LOST | 1001 |
| TTL | - | TRUE TARGET LOST | 1000 |
| FTNSA | - | FALSE TARGET NOT SUPPRESSED ADDED | 0101 |
| TTA | - | TRUE TARGET ADDED | 0100 |
| FTSA | - | FALSE TARGET SUPPRESSED ADDED | 0011 |
| FTA | - | FALSE TARGET ADDED | 0010 |
| BFTTA | - | BAD FALSE TARGET TABLE ENTRY | 0001 |

APPENDIX C

HAND ANALYSIS OF FIX 1

## C.1 Example

Figure C-1 is a reproduction of the COMDIG printout used to analyze fix 1 at IND. It lists all targets squawking 2771, 1671, 7257, 4677 or 3072 between 2140Z plus 17.3 sec and 2141Z plus 58.1 sec on CD record tape N928.

The target squawking 7257 is subject to ringaround during this time period. There are seven good reports from this target, marked 6, and nine ringaround reports, marked x, on the figure.

Assuming Fix 1 implemented with a radius of 11 nmi, 7 of the 9 ringaround reports should be eliminated by the fix. These are the seven occurring after 2141Z plus 9.5 sec. They are all associated with an altitude and a range such that the spare bit will be set.

The figures report for Fix 1 in subsections 5.1.1 and 5.1.2 were derived by proceeding in this manner, with printouts from the IND and QAS tapes.

DATE 06/07/77 COMDIG ROUTINE - LIST CD DATA PAGE 6

CD TEST RUN - NONE DATE - 03-29-77

CD SITE: IND

DATA REF - TRUE NORTH SITE DECLINA - NONE DATA TYPE - BEACON - 3/A SCAN INTERVAL - REGULAR

| TIME | IDENTIFICATION | | USER | RANGE N.M. | 1/8 | AZIMUTH DEGREES | ACPS | MODE 3/A | BEACON ALTITUDE | MODE 2 | TARGET RUN LENGTH | TIME IN STORAGE | DELTA TIME |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21/40/17.3 | 8C3 | DR | FA | 135 | 4 | 83.935 | 955 | 2771 | 35000. | | | .1 | 20.3 |
| 21/40/22.6 | 6C3 | DR | FA | 61 | 4 | 275.888 | 3139 | 1671 | 35000. | | | .1 | 20.1 |
| 21/40/23.1 | 8C3 | D | FA | 16 | 3 | 287.579 | 3272 | 7257 | 36800. | | | | 10.2 |
| 21/40/25.4 | 6C3 | D | FA | 3 | 3 | 13.974 | 159 | 4677 | - 1200. | | | .1 | 18.2 |
| 21/40/27.3 | 3C3 | DR | FA | 6 | 6 | 79.750 | 396 | 4677 | - 1200. | | | | 1.9 |
| 21/40/27.4 | 8C3 | DR | FA | 134 | 2 | 84.111 | 957 | 2771 | 35000. | | | .1 | 10.1 |
| 21/40/32.8 | 3C3 | DR | FA | 62 | 2 | 275.712 | 3137 | 1671 | 35000. | | | | 10.2 |
| 21/40/37.1 | 8C3 | D | FA | 122 | 1 | 72.421 | 824 | 3072 | 39000. | | | .1 | 20.1 |
| 21/40/37.6 | 6C3 | DR | FA | 133 | 0 | 83.935 | 955 | 2771 | 35000. | | | | 10.2 |
| 21/40/42.9 | 8C3 | DR | FA | 64 | 0 | 275.800 | 3138 | 1671 | 35000. | | | | 10.1 |
| 21/40/43.3 | 8C3 | DR | FA | 14 | 0 | 283.457 | 3282 X | 7257 X | 36300. ? | | | | 20.2 |
| 21/40/43.4 | 8C3 | D | FA | 13 | 7 | 291.621 | 3318 | 7257 G | 36800. | | | | .1 |
| 21/40/47.3 | 8C3 | D | FA | 121 | 0 | 72.333 | 823 | 3072 | 39000. | | | | 10.2 |
| 21/40/47.7 | 6C3 | DR | FA | 131 | 5 | 84.111 | 957 | 2771 | 35000. | | | | 10.6 |
| 21/40/53.1 | 8C3 | DR | FA | 65 | 2 | 275.712 | 3137 | 1671 | 35000. | | | | 10.2 |
| 21/40/53.5 | 8C3 | DR | FA | 12 | 6 | 293.115 | 3335 | 7257 G | 36800. | | | | 10.2 |
| 21/40/57.4 | 8C3 | DR | FA | 119 | 7 | 72.246 | 822 | 3072 | 39000. | | | | 10.1 |
| 21/40/57.5 | 8C3 | D | FA | 6 | 7 | 74.619 | 369 | 4677 | - 1200. | | | | 30.2 |
| 21/40/57.8 | 5C3 | DR | FA | 130 | 4 | 84.111 | 957 | 2771 | 35000. | | | | 10.1 |
| 21/41/03.5 | 8C3 | D | FA | 11 | 6 | 293.027 | 3334 | 7257 G | 36800. | | | | 10.0 |
| 21/41/07.5 | 9C3 | D | FA | 118 | 5 | 72.158 | 821 | 3072 | 39000. | | | | 10.1 |
| 21/41/07.5 | 3C3 | D | FA | 7 | 0 | 73.300 | 334 | 4677 | - 1200. | | | .1 | 10.0 |
| 21/41/07.9 | 8C3 | DR | FA | 129 | 2 | 84.199 | 959 | 2771 | 35000. | | | | 10.1 |
| 21/41/09.5 | 8 3 | D | FA | 11 | 1 | 141.679 | 1612 | 7257 X | 36800. | | | | 5.9 |
| 21/41/13.3 | 8C3 | DR | FA | 67 | 7 | 275.449 | 3134 | 1671 | 35000. | | | | 20.2 |
| 21/41/14.0 | 9C3 | D | FA | 10 | 5 | 297.619 | 3409 | 7257 G | 36800. | | | | 4.5 |
| 21/41/17.6 | 8C3 | DR | FA | 7 | 0 | 71.906 | 817 | 4677 | - 1200. | | | | 10.1 |
| 21/41/17.7 | 8C3 | D | FA | 117 | 4 | 72.070 | 820 | 3072 | 39000. | | | | 10.2 |
| 21/41/19.1 | 8C3 | D | FA | 10 | 2 | 6-.857 | 1011 | 7257 X | 36800. | | | | 4.1 |
| 21/41/23.4 | 8C3 | DR | FA | 69 | 1 | 275.273 | 3132 | 1671 | 35000. | | | | 10.1 |
| 21/41/24.2 | 6C3 | D | FA | 9 | 5 | 304.189 | 3461 | 7257 G | 36800. | | | | 6.1 |
| 21/41/27.7 | 8C3 | DR | FA | 7 | 1 | 79.664 | 904 | 4677 | - 1200. | | | | 10.1 |
| 21/41/28.1 | 6C3 | DR | FA | 126 | 6 | 84.287 | 959 | 2771 | 35000. | | | | 20.2 |
| 21/41/33.5 | 8C3 | DR | FA | 70 | 3 | 275.537 | 3135 | 1671 G | 35000. | | | | 10.1 |
| 21/41/37.7 | 8C3 | D | FA | 7 | 2 | 69.960 | 795 | 4677 | - 1200. | | | .1 | 10.0 |
| 21/41/37.9 | 8C3 | DR | FA | 115 | 2 | 71.962 | 819 | 3072 | 39000. | | | | 20.2 |
| 21/41/38.7 | 8C3 | D | FA | 8 | 4 | 99.931 | 1137 | 7257 X | 36800. | | | | 14.5 |
| 21/41/40.4 | 9C3 | D | FA | 8 | 3 | 163.564 | 1961 | 7257 X | 36800. | | | .1 | 1.7 |
| 21/41/41.0 | 8C3 | D | FA | 8 | 3 | 184.130 | 2095 | 7257 X | 36800. | | | | .6 |
| 21/41/45.8 | 8C3 | D | FA | 3 | 4 | 352.617 | 4012 | 4677 | - 1200. | | | | 6.1 |
| 21/41/48.2 | 8C3 | DR | FA | 124 | 2 | 84.550 | 962 | 2771 | 35000. | | | .1 | 20.1 |
| 21/41/49.7 | 6C3 | D | FA | 3 | 0 | 12-.144 | 1459 | 7257 X | 36800. | | | | 8.7 |
| 21/41/50.1 | 6C3 | D | FA | 7 | 7 | 153.105 | 1742 | 7257 X | 36800. | | | | .6 |
| 21/41/51.1 | 8C3 | D | FA | 7 | 7 | 186.855 | 2126 | 7257 X | 36800. | | | .1 | .8 |
| 21/41/53.6 | 8C3 | DR1 | FA | 72 | 7 | 275.097 | 3130 | 1671 | 35000. | | | .1 | 20.1 |
| 21/41/55.4 | 8C3 | D | FA | 7 | 6 | 335.445 | 3828 | 7257 G | 36800. | | | | 4.3 |
| 21/41/58.1 | 3C3 | DR | FA | 7 | 3 | 72.509 | 825 | 4677 | - 1200. | | | | 12.3 |



Figure C.1. Example of COMDIG Printout